THE UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR ...Keith Douglas Horton...............

TITLE OF THESIS ...Phonemic Similarity, Rehearsal,...

...and Short-term Memory.............

....

DEGREE FOR WHICH THESIS WAS PRESENTED ...MSc...............

YEAR THIS DEGREE GRANTED ...1975...............

DATED ...Dec. 5.......

THE UNIVERSITY OF ALBERTA

PHONEMIC SIMILARITY, REHEARSAL, AND SHORT-TERM MEMORY

by

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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF PSYCHOLOGY

EDMONTON, ALBERTA

SPRING, 1975

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled "Phonemic Similarity, Rehearsal, and Short-term Memory" submitted by Keith Douglas Horton in partial fulfilment of the requirements for the degree of Master of Science.

Date. Dec 5 . 1974 .

ABSTRACT

The present research investigated the processing and storage of phonemically-related items in short-term store (STS). The major findings were that these items tended to be recalled better than the control items but that this could not be explained on the basis of either the absolute or normalized number of rehearsals accorded the related items. Further, strong evidence was obtained in support of Glanzer's (1972) notion that related items tend to be reorganized into groups in STS, and that such reorganization was strongly correlated with recall of the critical items as a group.

The second issue of concern was the capacity of STS (Pi). A number of serious criticisms were put forth with respect to the traditional methods of calculating Pi, most of which lead to an underestimation of Pi. An alternative means of assessing Pi based on the contents of the final rehearsal set was offerred. This alternative method was unaffected by most of the above problems. A comparison of the obtained estimates revealed substantial differences in the traditional methods compared to the newly-proposed method.

ACKNOWLEDGMENTS

The author wishes to thank committee members Dr. P.A. Runquist and Dr. S.T. Carey for their insightful comments on an earlier draft of the paper.

Many thanks are also due to Bryce Schurr and Berry Hsu for their invaluable assistance in the modification of the computer program used to compile the otherwise formidable reams of data which were generated in the present study.

A special debt of gratitude is owing to my supervisor, Dr. W.N. Runquist. His encouragement, advice, and contributions in many different forms were highly instrumental at all stages of this thesis.

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The purpose of the present research was to investigate the processing and storage of phonemically related items (i.e., homophones). While traditional theories have allocated processing and storage effects of phonemic similarity to short-term memory, a recent conceptualization offerred by Glanzer (1972) suggests this may be erroneous. The argument put forth by Glanzer is that while early research is suggestive of the traditional theoretical view, it is at best inconclusive because the techniques used have been inadequate for determining whether effects of phonemic attributes are based in a short-term or a long-term memory system. The present experiment was designed to shed light on this general issue by means of the Rundus overt rehearsal technique (Rundus and Atkinson, 1970; Rundus, 1971).

As the theoretical and empirical work dealing with the effects of phonemic similarity has been voluminous, we shall begin be elucidating the essential developments leading up to the traditional views, including those of Glanzer.

A critical issue in the recent history of theory and research on human memory has been the distinction between different storage systems within the larger memory system. The majority of theorists dealing with this issue have espoused the delineation of either two or three such storage systems (e.g., Broadbent, 1958; Waugh and Norman, 1965; Atkinson and Shiffrin, 1968) although others have opted for a version of a unitary model (e.g., Craik and Lockhart, 1972; Murdock, 1972). Wickelgren (1973) has very recently

concluded that a multiple storage model may be interpreted to fit the existing data but a unitary model can equally account for most of these results.

The most common distinctions within the multiple storage models have been a sensory register, short-term memory (or primary memory), and long-term memory (or secondary memory). Each of these systems is generally assumed to have certain characteristics. The sensory register is acknowledged to have a large capacity for storing input but, because it is assumed to be represented essentially as the peripheral neural traces, decay of information in the register is very rapid. Although Sperling's (1960) research accredited the sensory register as a distinct system, it is the other two systems which have received the majority of attention in the literature.

Short-term memory, or STM, is traditionally referred to as a low capacity storage system, with a maximum capacity of about five to seven items. Information is lost through decay, if it is unrehearsed, displacement by newly-arriving input, or by a combination of decay and displacement. The decay theorists generally give the STM trace a lifespan of approximately 10 to 15 seconds before it is lost completely.

In contrast, long-term memory, or LTM, is a very large capacity storage system, often hypothesized as having no upper limit. Loss of information from this system is as yet an unresolved issue: some suggest that information is never lost, while others postulate loss due to interference among

traces or loss due to decay, or "disuse".

In an attempt to justify the theoretical distinction between STM and LTM, it has often been assumed (explicitly or otherwise) that there is a need to show that different variables have differential effects on the STM and LTM components in recall (e.g., Kintsch, 1970; Baddeley, 1972; Jung, 1968; see also Wickelgren, 1973). Included in the many variables which have been investigated in accord with this assumption are presentation rate (e.g., Raymond, 1969), list length (e.g., Murdock, 1962), phonemic and semantic, or conceptual, similarity (e.g., Dale and Gregory, 1966), and modality effects (e.g., Murdock and Walker, 1969). As a reasonable generalization, it is fair to conclude that a large number of variables have been shown to have a major effect on the presumed LTM component in recall (e.g., list length, presentation rate, semantic similarity) whereas a few have had an effect on the presumed STM component (e.g., phonemic similarity, delay interval prior to test).

Of the myriad of variables which have been the focus of attention, probably none has had more theoretical prominence or empirical consideration than similarity (for a review, see Shulman, 1971). Much research by Baddeley (1966 a, b; 1968; Baddeley and Dale, 1966), Conrad (1959; 1963; 1964; Conrad, Baddeley, and Hull, 1966; Conrad, Freeman, and Hull, 1965), and Wickelgren (1965 a, b, c; 1966) has led many investigators to the conclusion that items are stored in STM by means of a "phonemic" (see Shulman, 1971, p. 400) code

whereas items in LTM are represented as a semantic (i.e., meaning) code (e.g., Conrad, 1967). This conclusion has been based on the general finding that errors of a phonemic variety are typically observed when recall is from the experimentally-defined STM, whereas errors are typically semantic when recall is from the experimentally-defined LTM. It should be noted, however, that some authors have remained unconvinced about this strict differentiation of STM and LTM as based on phonemic and semantic coding respectively. Shulman (1971) has acknowledged the "...undeniable salience of phonemic similarity in short-term memory..." (p. 407) but also asserts that "there is little doubt that short-term memory is affected by semantic similarity" (p. 412). With regards to the form of coding used in LTM, Shulman notes that many studies have demonstrated effects of semantic similarity (p. 412) but in addition he cites evidence suggesting that "phonemic attributes...can be represented in long-term store..." (p. 405). Baddeley (1972) concurs that phonemic and semantic attributes are coded into STM and LTM respectively, but that STM "...is relatively insensitive to semantic factors..." and LTM is basically unaffected by the phonemic attributes of items (p. 379). Baddeley's argument is based on the conclusion that all studies which have presumed to show semantic similarity effects in STM have not been able to eliminate the LTM component from recall.

There are many examples of this ambiguous situation in the literature. One is a recent study by Shulman (1972,

Expt. I) in which Ss were required to indicate if a probe word was identical or similar in meaning to any word in a 10-item target set presented immediately prior to the probe. No test was given to see how well Ss knew the target set and no time limit was given for the recognition response. On the basis of the widely assumed characteristics of STM mentioned above, it is obvious that the target set exceeds the capacity of STM. Furthermore, there is no justification on the basis of this experiment for assuming that semantic codes for most if not all of the target items have not been established in LTM at the time of presentation of the probe item. Thus, this experiment can not reasonably allow one to conclude that semantic codes can be represented in STM as well as in LTM, as Shulman suggests. Rather, the recognition task may well have involved LTM storage given the unlimited test interval.

Baddeley cites evidence which he argues leads to the conclusion that data suggesting semantic similarity effects in STM may be the result of semantic codes, or rules, which have been established in LTM. These codes operate at the time of recall "...to interpret phonemically coded primary memory traces..." (p. 379). In support of such an interpretation, Baddeley and Ecob (1970) have shown that both acoustic and semantic characteristics of items affected immediate recall of word triads, but only semantic characteristics had any sizeable effect on recall after a 20-second delay period. This suggested to the authors that the semantic characteristics of the items were coded into

LTM by means of retrieval rules while the phonemic attributes were available as the STM representation of the items. Both codes could be used to retrieve items for immediate recall but only the semantic retrieval rule was available for delayed recall.

There is, then, a general and critical theoretical need to distinguish effects on recall which are restricted to the STM and the LTM components respectively. This point has been made previously by Kintsch (1970). The STM component may be removed from recall so as to observe the LTM component independently simply by introducing a delay task of a given duration immediately following presentation of the to-be-remembered (TBR) items, by using a sufficient number of interpolated items, or by an appropriate combination of the two. However, we may not be able to eliminate the LTM component from recall so as to evaluate the STM component independently. Part of the problem is that we cannot assess the transfer of information from STM to LTM. A further complication is that it may be difficult to determine whether an item (or a list intrusion) was recalled from STM or LTM since some theoretical interpretations allow that an item may exist concurrently in both memory systems.

Glanzer (1972) has recently taken as a primary line of inquiry this issue of empirically distinguishing between these two memory components in recall. Using the same arguments as Baddeley, Glanzer contends that because few

studies have made a definitive empirical distinction between the STM and LTM components in recall, they cannot logically be used to define or assess the characteristics of STM or LTM: obviously, the two will be confounded in recall. Both Baddeley and Glanzer suggest that by interpolating a delay task immediately following presentation of the TBR items, the contents of STM can essentially be erased. Thus, what is recalled after the delay represents the LTM component of memory. Although the two authors equally appreciate that earlier research has not allowed a distinction between STM and LTM components in recall and both wish to attack the problem by interpolating a delay task prior to recall so as to eliminate the STM component, their conclusions are very different. This is true specifically when each accounts for the effects of mnemonic relationships between list items.[1] Baddeley, as we noted earlier, presented evidence suggesting that recall from STM was affected by phonemic similarity whereas recall from LTM was affected by semantic similarity. However, on the basis of some of his own research (e.g., Glanzer, Koppenaal, and Nelson, 1972), Glanzer argues that mnemonic structure, either phonemic or semantic, has absolutely no effect on recall of items from STM as evidenced by the failure to find an increase in the number of items recalled in the STM component. However, each of these attributes did increase recall performance from the

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[1]A mnemonic relationship between a group of items is defined as a common attribute which facilitates organization of these items (Glanzer and Schwartz, 1971). Phonemic and semantic attributes are the mnemonic relationships referred to herein.

LTM component. The difference in the points of view of Baddeley and Glanzer, then, is in the source of the effect of phonemic similarity. Baddeley's interpretation is typical of the commonly held belief, as mentioned above, that STM utilizes phonemic coding and LTM utilizes semantic coding.

Since Glanzer's interpretation of the effects of phonemic similarity is somewhat contradictory to the generally accepted interpretation and also because Glanzer's view is part of a more complete theory of memory which he proposes, it would seem appropriate at this point to elaborate more fully on his more general approach to memory and processes operating within it.

Glanzer's Theory of Memory

Glanzer's initial assumption, of course, is that there is a multiple-store memory system. Although he acknowledges the sensory register as a distinct system, his interest lies primarily in the short-term store (STS) and long-term store (LTS). (Glanzer adopts the convention of referring to STS and LTS as theoretical constructs and STM and LTM as the experimental referents of these constructs. We shall observe this distinction throughout the remainder of the paper.) With regard to STS and LTS, Glanzer is essentially in agreement with a number of other theorists concerning the functioning of these two storage systems (see Atkinson and Shiffrin, 1968; Waugh and Norman, 1965).

According to Glanzer, "STS functions as an input buffer" which maintains an item temporarily in the memory system so that it may be "available for further processing" (Glanzer, 1972, p. 141). Once an item has entered STS, it may be displaced from there by a newly-arriving item or may otherwise become "unavailable".

The former characteristic reflects the limited capacity nature of STS. However, it is not so obvious exactly what Glanzer means by an item becoming unavailable, especially in light of his later comments concerning a displacement versus decay process in STS (cf p. 145) and his method of calculating the capacity of STS (cf p. 151). The size of STS is derived from the sum of the estimates of Pi(STS) (the probability of the _I_th item of a list being recalled from STS). This sum is based on the last five items of the input list. If this value is to be a reasonable estimate of the capacity of STS, then it must be assumed that recall from STS is essentially exhaustive. This argument is in agreement with Glanzer's suggestion that "access to information in STS is relatively direct" (p. 131).

Also, Glanzer argues that decay does not appear to operate in STS as earlier authors have suggested (e.g., Brown, 1958); rather, items are lost from STS due to their being displaced by other items. Thus, if an item either is or is not in STS, as opposed to being partially lost through decay, and if recall from STS is essentially exhaustive, then it remains unclear exactly what Glanzer means by an

item in STS becoming "unavailable". This proposition of Glanzer's will be dealt with further.

While an item exists in STS, LTS is presumed to initiate an analysis of that item and store a coded representation of the information obtained. The transmission of information to LTS does not necessitate the removal of the item from STS; thus, an item can be represented in both storage systems simultaneously and, according to Glanzer, independently. The assumption of independence reasserts the proposition that transfer of an item into LTS has no effect on that item's existence in STS and is the same assumption made in an earlier paper by Waugh and Norman (1965). This assumption becomes somewhat critical when Glanzer calculates the STS component in recall and the capacity of STS as a function of a multitude of experimental manipulations.

Much of the theory to this point is similar to a variety of other theories which predate Glanzer's. However, that is where the similarity ends.

In an attempt to determine the characteristics of storage in the two memory systems, Glanzer reviews a number of empirical studies. Due to the problem of empirically separating STS and LTS components in recall, Glanzer has been forced into a highly selective review of the literature. What the results of these studies appear to show, according to Glanzer, is that "STS is a very robust, insensitive mechanism that responds to nothing except the

passage of items through it" (1972, p. 148). The exceptions to this rule are modality of presentation and grouping of items at input (see Glanzer, 1972, p. 184ff). Virtually all variables which are reputed to have an effect on recall do so in LTS. Glanzer's own research deals with many of these variables. One is of particular interest to us in the present paper: mnemonic relationships among the TBR items within a list.

AMOUNT OF INFORMATION STORED IN LTS

As noted earlier in the paper, most theorists and investigators have agreed that phonemic similarity among TBR items has an effect at least in STM and semantic, or conceptual, similarity has an effect at least in LTM. This, we noted, suggested to many authors that an item was stored in a phonemic form in STM and in a semantic form in LTM. Some authors of late, however, have suggested that semantic and phonemic similarity may each affect both STM and LTM (e.g., Shulman, 1971). As a generalization, though, these authors essentially agree that the number of items recalled from both STM and LTM are affected by some form of a mnemonic relation among list items. Glanzer agrees that this variable has an effect on the experimentally-defined STM, but because STS was not separated from LTS, there is no resolution to the problem of whether the effects in STS and LTS were different (see Glanzer, 1972, p. 175ff). Those studies which have experimentally separated STS and LTS, Glanzer argues, have been somewhat equivocal. For example,

from the free recall (FR) literature, Craik and Levy (1970) found that phonemic similarity had no significant effect on the number of items recalled from STS. A similar finding was observed by Posner and Konick (1966) with the distractor technique. Using the probe technique, in which recall of a given item is tested by presenting the immediately preceding item in the list, Levy and Murdock (1968, Expt. II) and Kintsch and Buschke (1969) found that phonemic similarity decreased the amount held in STS. This is the traditional effect in STM of phonemic similarity. A paired-associate probe task has also yielded a decrease in the amount recalled from STM (Kintsch and Buschke, 1969) or no effect (Bruce and Murdock, 1968). With respect to the effects of phonemic similarity on LTS, the FR data indicates an increase in recall (Bruce and Crowley, 1970; Craik and Levy, 1970) as does the distractor technique (Posner and Konick, 1966). The probe recall studies demonstrated either no effect (Levy and Murdock, 1968) or an increase (Bruce and Murdock, 1968) in recall from LTS.

In summary, Glanzer states that "...the effects of similarity on LTS and STS are not established" (1972, p. 178). There are some points to be made, however, which are not clear on the basis of Glanzer's remarks and which, subsequently, may have an effect on the above conclusion. First, a minor point is that Glanzer accepts the Kintsch and Buschke and Levy and Murdock results as evidence that phonemic similarity may affect the amount held in STS. This conclusion is based on interactions with the serial position

(SP) curve, despite the fact that this had been previously referred to as only "...a crude method of separating LTS and STS effects" (1972, p. 135). It might seem that if the SP curve alone is an inadequate means of distinguishing STS and LTS components of recall, then these two sets of results at best only suggest the effect which the respective authors outlined. It would appear equally possible however that their observed effects were based on items recalled from LTS. The source of the effect, then, is undetermined, despite Glanzer's apparent resignation to an STS interpretation.

A second and related point involves Glanzer's reference to the Posner and Konick (1966, Expt's III and IV) study. This study used the Brown-Peterson paradigm (Brown, 1958; Peterson and Peterson, 1959) to look at the effects on recall of the confusability of the TBR items after varying intervals of a delay task. It was found that there were different lower asymptotes for the forgetting curves of the high and low similarity conditions but no difference was found in the slopes, or rate of approach, to the respective asymptotes. These two findings suggested to Glanzer that similarity had an effect on the LTS component of recall (i.e., different asymptotes) but not on the STS components (i.e., same rate of approach). However, there were no estimates of recall from STS according to the Waugh and Norman (1965) technique, although Glanzer earlier expressed much faith in this calculation (e.g., 1972, p. 136ff). It would seem appropriate for Glanzer to have applied this

calculation to the data before drawing any conclusions about the effect of the similarity manipulation on STS.

A final point is particularly puzzling. Glanzer and Meinzer (1968) attempted to investigate the effect of mnemonic structure on STS and LTS. Their lists were of two types: in one, every item in the list was semantically related to one other item; in the other list, all items were unrelated. Their findings were not in support of the hypothesis that mnemonic structure would affect LTS but not STS. Glanzer and Schwartz (1971) later argued that this study did not pose a reasonable test of the hypothesis because it was possible that Ss developed different strategies for storing and retrieving the two different types of lists. The Glanzer and Schwartz study manipulated mnemonic structure as a within-list variable in an attempt to minimize the utilization of different strategies for the different types of items. However, Glanzer (1972) makes use of the results of Levy and Murdock (1968) and Kintsch and Buschke (1969) in the section of his paper dealing with mnemonic structure without acknowledging that both of these studies used lists which were constructed on the same format as those of Glanzer and Meinzer. Thus, it would seem reasonable that both of these other studies may have fallen subject to the same confounding effects of Ss employing different strategies for different lists. This speculation is supported by Kintsch and Buschke's remarks on how Ss reported studying the lists which were high in phonemic similarity. The authors report that Ss would attempt to

avoid the phonemic characteristics of items once they realized that the list was constructed of phonemically similar pairs. It is readily apparent that strategies by Ss could have very unpredictable effects on the results of the experiment. It also seems reasonable that the Craik and Levy (1970) experiment, which showed no effect of phonemic similarity on recall from STS, suffers from a similar problem since their lists were constructed with a blocked set of six phonemically similar items within a list of otherwise unrelated items. In this case, Ss may have been able to develop an appropriate strategy to make use of the relationship, rather than avoid it. Obviously, this strategy also could have unpredictable effects on recall.

Thus, although Glanzer and Schwartz have analyzed the problem and have even reported differential results as a function of the two methods of incorporating the similarity variable, Glanzer (1972) has ignored the problem completely in his review of similarity effects.

There is a general problem, then, in determining Glanzer's exact position on certain issues, since, at least in the three points outlined above, Glanzer appears to be detailing an important issue but later effectively ignores his own arguments. However, on the basis of Glanzer's own conclusion (1972, p. 178), it appears that the effects of similarity on STS are as yet unresolved. Even this conclusion, however, must be accepted with some reservation. Glanzer, Koppenaal, and Nelson (1972, Expt. I) very clearly

and deliberately state that there is no effect of phonemic similarity on the amount held in STS (p. 408).

The purpose of the present research was to investigate the effects of phonemic similarity on STS in somewhat more detail and, hopefully, with more precision than has been accomplished to date. A variety of issues will be of interest in this respect. Each will be dealt with in turn. The first issue is the effect of phonemic similarity on the amount of information stored in STS. Glanzer's remarks on this particular issue have been outlined above. Glanzer considers how STS may be affected in other ways, also. These deal specifically with the operations or processes which may be enacted on an item in STS so as to increase the probability that the item will be stored in STS long enough to ensure that it will be transferred to LTS. Three such processes are specified. They are covert rehearsal, overt rehearsal, and the setting up of a mnemonic structure, or a mnemonic organization.

REHEARSAL

Overt and covert rehearsal, Glanzer says, have the effect of cycling the rehearsed item back through the system and thus, in a functional sense, maintaining the item in STS for a longer period of time. As a result of this maintenance function of rehearsal, there will be an increased probability that the item will be transferred to LTS, or in operational terms, there will be a greater

probability of the item being recalled in the LTS component of recall. This theoretical conclusion, however, is not completely supported by the extant literature. For example, Jacoby (1973, Expt. I) presented Ss with a list of 20 items presented in four blocks of five words with a delay task interpolated between each block of words. The delay periods were of three types: silent, filled with a subtraction task, or filled with overt rehearsal of the immediately preceding set. The delay interval was always 15 seconds in duration. If overt and covert rehearsal of an item serve to maintain an item in STS which directly increases the probability of that item being transferred to LTS, then it would be expected that the silent and overt rehearsal conditions would result in superior recall across all list positions compared to the subtraction condition. In this latter case, the subtraction task should effectively wipe out the list items through the process of displacement. Thus, only information which had been transferred to LTS prior to the onset of the subtraction task (or, at least, during the first few seconds of subtraction) would ever be registered in LTS. The findings showed that the subtraction task resulted in poorer recall than the silent condition across all input positions, as was expected. However, contrary to Glanzer's expectations, overt rehearsal produced poorer recall than the subtraction task in the first three blocks of words, despite the fact that the overt rehearsal strategy apparently maintained items in STS much more effectively than did the subtraction condition. This is evident from

Fig. 1 of Jacoby's report which shows a very high degree of recall (89%) in the overt rehearsal condition for the last block of five words presented but substantially poorer recall of these items in the subtraction condition. In fact, the latter condition resulted in a recall probability of only 0.37 for the last block of items compared to an overall recall probability of 0.28 for the first three blocks. These data lend support to the suggestion that the subtraction task had a strong tendency to eliminate the list items from STS whereas overt rehearsal tended to maintain the items in STS.

An increasing number of additional studies have also shown that increasing the number of rehearsals given to an item, and thus increasing that item's duration in STS, does not _per se_ increase the probability that the item will be transferred to LTS (e.g. Meunier, Ritz, and Meunier, 1972; Jacoby and Bartz, 1972; Craik, Gardiner, and Watkins, 1970; Craik and Watkins, 1973). Each of these studies showed that immediate FR of the TBR items was better after a delay interval filled with rehearsal than the same interval filled with an interpolated task, but that a final unexpected FR test of all lists presented yielded virtually identical results for the two delay conditions. The proposition which these studies appear to repudiate has been put forth in a number of respected theories, besides Glanzer's. These theories include those of Waugh and Norman, (1965), Atkinson and Shiffrin (1968), and Norman and Rumelhart (1970), all of which state that there is a direct relationship between the

length of stay of an item in STS (or its equivalent in the various theories) and the eventual probability that the item will be recalled from LTS. It is important to emphasize this observed empirical characteristic of rehearsal time as it relates to storage in LTS as it is a critical point in the research to be reported. It is the opinion of some authors (Weist, 1972; Jacoby and Bartz, 1972; Jacoby, 1973; Craik and Watkins, 1973), including the present one, that number of rehearsals <u>per se</u> has no direct effect on storage in LTS. Rather, an item which is being rehearsed may be involved in a higher level processing stage, the outcome of which may result in a more permanent and available record of that item than can be achieved through a mere "passive" rehearsal strategy on the part of <u>S</u>. This viewpoint would predict a positive relationship between the number of rehearsals and the probability of recalling the item from LTS while at the same time permit an explanation of "negative recency" similar to that of Mazuryk (1974).

Evidence in favour of this latter point of view is clear. Rundus (Rundus and Atkinson, 1970; Rundus, 1971) has recently developed a technique whereby <u>S</u>s rapidly and overtly rehearse during the presentation interval whichever items from the list about which they "are currently thinking". Using this technique, Rundus has shown a strong positive relation between the number of overt rehearsals accorded an item and the probability of recalling that item from LTS (i.e., the asymptote of the FR curve). This only requires the assumption that the number of rehearsals of

these items directly reflects the amount of processing given them. The strong correlation is wiped out when the items are recalled from the STS component (i.e., the recency portion of the FR curve), as was indicated above.

When dealing with the overt rehearsal technique developed by Rundus, it is of value to note a very critical assumption which is involved. Rundus and Atkinson (1970), along with most other investigators who use the technique, assume that an item which is rehearsed overtly comes from STS. This does not preclude the possibility that the item may also be in LTS concurrently, which, as Glanzer suggests, may be quite feasible; rather, it is only assumed that an item will not be overtly rehearsed directly from LTS. This assumption does not seem unrealistic in light of the traditional assumption that recall from STS is relatively direct whereas recall from LTS is a somewhat more involved and time-consuming process. In addition to this, the overt rehearsal instructions given to Ss generally encourage a reasonably rapid rate of rehearsing. For Ss to attempt recall from LTS under these conditions would seem both difficult and wasteful.

The present research relies to a large degree on the assumption that overt rehearsal reflects the contents of STS only.

REHEARSAL AND ORGANIZATION IN STS

Another issue related to the one outlined above has been raised by some authors of late. This issue deals with determining the cause of the observed relationship between the number of rehearsals and the probability of recall of the individual item. Atkinson and Shiffrin (1968) suggested that the rehearsal of an item serves simply to reinstate a copy of the item in STS such that it will be readily available for encoding into LTS. Within this model, however, there is no allowance for changes in rehearsal patterns as a function of relationships of any sort among list items. For rehearsal to respond so automatically to the input of items appears naive at both an intuitive level and an empirical level (e.g., Weist, 1972; Expt. II).

At first glance, it appears that Glanzer takes a position similar to that of Atkinson and Shiffrin when he states as a generalization that "STS is a very robust, insensitive mechanism that responds to nothing except the passage of items through it" (1972, p. 148). However, Glanzer goes on to say, as was noted above, that a mnemonic organization may be imposed on STS. Since no processing occurs in STS itself, then the source of this processing must be in LTS. Thus, for any organization or restructuring of information to occur in STS, two conditions must necessarily be satisfied: first, the item must have been processed in LTS; second, the dimension along which the organization occurs must reflect a functional dimension of

coding and storage in LTS. With regard to the specific interest of the present paper, namely phonemic attributes, the second condition appears to be satisfied. A number of studies have shown that phonemic similarity does have an influence on the number of items recalled from the LTS component (e.g., Bruce and Crowley, 1970; Craik and Levy, 1970). As was noted previously, however, there does exist a certain amount of disagreement on this point (e.g., Baddeley, 1972; Kintsch and Buschke, 1969).

In considering the first necessary condition, a logical dilemma develops: if it is necessary for an item to be processed in LTS before it may be involved in a reorganization of items in STS, then what purpose is served by the reorganization? The information relevant to the reorganization has already been processed or analyzed in LTS. Any reorganization then would merely be a redundant and unnecessary feature of the memory system. At best, it serves no purpose. At worst, it could take valuable processing time away from other items.

In reply to this criticism, it might be responded that reorganization of STS on the basis of phonemic attributes would allow more time for the semantic analysis to occur. This appears to be a useful endeavour on the part of the system since recent research suggests that long-term retention, or at least accessibility, of phonemic information is inferior to that of semantic information (Jacoby and Goolkasian, 1973). The major problem with this

suggestion is that homophones are not likely to be related to each other in any semantic or categorical way. Thus a reorganization of items on the basis of phonemic characteristics would not appear to facilitate the storage of semantically related sets of items.

In summarizing Glanzer's position, it appears that the role of rehearsal is simply to reinstate a copy of a given item in STS. The reorganization of items in STS originates in LTS, not in STS itself. Thus, rehearsal of the contents of STS can only reflect the state of affairs in STS: it cannot influence this state.

Other investigators have suggested a more active role for rehearsal in the identification and storage of items. Weist (1972) has proposed a system whereby the activation of stored features (syntactic-semantic, imaginal, phonemic) in LTS results in these features being transferred into "working memory". (For simplicity, we will equate Weist's working memory with Glanzer's STS.) The maintenance of the item and its corresponding features in STS (however it is proposed that they be stored) permits the detection of other items with common features by a process of memory search. This search involves comparing recently activated features with those which are currently in STS. The matching or discovery of common features results in the reorganization and reconstruction of items in STS. Such "lexical cross-referencing" is the proposed source of grouping behaviour during rehearsal and recall. This grouping results in the

development and revision of retrieval plans or strategies. Thus, rehearsal clearly is not the source of the reconstruction or reorganization of STS as Weist suggests; rather, rehearsal only mirrors the result of a process which originates in LTS.

Rundus (1971) has suggested that assigning a causal role to rehearsal may be a dubious assumption, although he does speculate that overt rehearsal may effect STS storage changes based on phonemic characteristics of the rehearsed items (1973, personal communication). This would result from the additional emphasis given these particular features through the act of saying the items aloud, a suggestion which does not seem unreasonable. This general view is not unrelated to recent suggestions by Underwood (1972) that various characteristics of list items may become increasingly relevant dimensions of encoding as a result of the experimental manipulations.

ORGANIZATION AND STORAGE IN STS

It will be recalled that Glanzer suggests a reorganization of items in STS may help to maintain those items in STS. The suggestion, then, is that any pair of items which are, for any reason, reorganized into a functional pair in STS, as a consequence, may tend to stay there longer. If they do, this will increase the probability that they will be stored in LTS as a functional pair and subsequently be recalled with an increased

probability.

There is some empirical evidence relating to this hypothesis. Glanzer, Koppenaal, and Nelson (1972, Expt. I) manipulated phonemic similarity as a within-list variable. Each list contained four pairs of similar words plus four unrelated control words. Three types of similarity were used, the differences between similar pairs being in the first phoneme, the vowel, or the final consonant. Within each list, each type of similarity occurred at least once. Based on the finding that the presence of phonemically related items in the final list positions did not increase recall from STS, the investigators concluded that the presence of a phonemically similar item did not increase the probability that the related item stayed in STS longer than a given control item. No measure of organization in STS was taken so it is impossible to assess this aspect of the hypothesis. If, in this particular study, Ss did not reorganize the related items into pairs in STS, then on the basis of Glanzer's remarks, there would be no particular reason to expect those items to stay in STS longer than normal: apparently, the reorganization itself is directly related to any increase in duration of an item's stay in STS.

Clearly, however, phonemic similarity increased recall from LTS (see their Fig. 1), implying that the variable was being registered. It is not clear, then, under what conditions Glanzer might expect the related items to be

reorganized within STS and consequently stay there longer than normal.

An early study by Glanzer and Meinzer (1967) may provide a clue. It will be recalled that this study was intended to test the hypothesis that the effects of within-list mnemonic structure would be restricted to recall from LTS. Similarity was manipulated as a between-list variable such that each list was either made up completely of pairs of related items or all items were unrelated to all others. It seems reasonable that under these conditions of near-maximum similarity, _S_s might well make use of a strategy such as regrouping pairs of items in STS. Such a strategy would seem very practical since all items may be regrouped, whereas in the situation of similarity being manipulated as a within-list variable, _S_s would be required to determine for each successive item whether a related item had occurred earlier in the list. In this latter situation, such a strategy would probably prove wasteful of valuable processing time since not all items would provide a match; in the former situation, the strategy would be rewarded every time the second member of a pair was presented and thus, theoretically, could eventuate in an increased degree of recall from LTS.

The results of the experiment suggested to Glanzer and Meinzer that the effects of similarity were not as they hypothesized: there was an increase in recall from both STS and LTS. Unfortunately, however, the study did not utilize

an effective delay condition: the delay task did not clear the final list items from STS, as evidenced by the persistence of the recency effect. Consequently, STS and LTS components were separated by means of the serial position curves. Apparently, there has been no further empirical attempt to run a delay condition subsequent to a high similarity list of the sort used by Glanzer and Meinzer in which the delay task adequately removed the recency items from STS. This must necessarily restrict any comments concerning how reorganization may affect STS and LTS since this particular means of manipulating similarity should theoretically maximize the value of reorganization.

A further and probably more crucial restriction must be imposed on statements of the effects of reorganization in STS on recall from STS or LTS. It would seem imperative that a direct measure be taken of grouping strategies, since this is a primary link in the chain of events which Glanzer proposes will lead to improved recall.

The Rundus overt rehearsal technique may satisfy this need. As has been mentioned previously, this technique has been used with success to assess grouping strategies as a function of semantic or conceptual similarity and as a function of learning trials (e.g., Rundus and Atkinson, 1970). Einstein et al (1974) used the overt rehearsal technique with lists of 24 unrelated items. Their data (see their Table 5) show a highly significant relationship between the number of times a given pair of items occurred

successively in rehearsal and the probability of that pair being recalled together.

No research has been initiated using the overt rehearsal technique to analyze organization in STS as a function of within-list phonemic similarity. This was one purpose of the present research. Two independent groups of Ss were run in the present study. A control group (C) received only normal study instructions for the FR lists. A second group (E) was further required to overtly rehearse while they were studying the list.

Since most of the extant research using the technique of overt rehearsal has led to the generalization that storage in LTS is decremented by requiring Ss to overtly practice the list items, it would seem valuable to demonstrate that this decline in overall performance is not the result of Ss in the E condition studying the list differently than the control Ss who do not overtly rehearse. In other words, if we are to interpret overt rehearsal (OR) data as reflecting processing of items, it would seem necessary to show that the Ss in the present study were not studying and storing list items differently from Ss who do not overtly rehearse.

In order that we might generalize the processing of the E group to the C group, a number of empirical considerations were deemed relevant. First, if the two groups were approaching the general task of list learning in essentially the same manner, independent of relationships among list

items, then we might expect the overall shape of the SP curve to be similar for the two groups. Secondly, the overall number of related and unrelated items recalled would be expected to show no consistent differences between the two groups since this might otherwise reflect different study behaviours or strategies as a function of the overt rehearsal manipulation. In other words, we would not expect, for example, the experimental Ss to recall consistently more related items and consistently less unrelated items as a direct result of the overt rehearsal requirement in any way facilitating the storage of phonemic information. Finally, if the overlapping phonemic characteristics of the related items are encoded and stored in a similar fashion across the two conditions, the observed probability of pairwise recall of the related items should be be comparable. If these three basic condition are satisfied, we might suggest that the two groups were studying and storing the lists in the same manner. Each of these considerations is dealt with in the RESULTS.

In the present study, Ss were presented with 18 lists of 12 items each. Within 16 of the lists was embedded either two (R2) or three (R3) homophones. No list contained more than one set of these related items.

There was a particular reason for using these very minimal degrees of similarity in the present study. This was the problem of Ss attempting to use an unspecified strategy for studying the list. As was mentioned earlier,

this issue has been raised by Glanzer and Schwartz with reference to the Glanzer and Meinzer study. It was felt by the present author, however, that quite possibly even the relatively high degree of similarity which was used by Glanzer and Schwartz (8 of 16 list items were members of a phonemically similar pair) and later by Glanzer, Koppenaal, and Nelson (8 of 12 items were members of a related pair) may also have led Ss to attempt an invalidating strategy. It was stated above that this activity on the part of Ss might seem appropriate given the finding that retrieval of phonemic information from LTS is apparently poorer than, for example, retrieval of semantic information (Jacoby and Goolkasian, 1973). Elaboration of this point is necessary since it will be recalled that different results were obtained as a function of the amount of similarity within the lists.

Assume for the moment that all three of the studies mentioned above led to Ss utilizing a strategy different from that of Ss in the present study. For example, as was proposed earlier, maybe the former Ss endeavoured to search through the recently presented items (or the features which each aroused and transferred to working memory, as per Weist, 1972) to locate a similar item which, when found, would be rehearsed together with the present item. As Glanzer suggests, this series of events may theoretically improve the storage of the pair in LTS. Again, each time the second member of a pair was presented in the Glanzer and Meinzer study a match may be found whereas in the Glanzer

and Schwartz and Glanzer, Koppenaal, and Nelson studies a match could only have been found for approximately half of these searches. Those searches which proved unsuccessful would, on the average, take more processing time than the successful ones. Therefore, there is a longer period of search time involved in the Glanzer and Schwartz and Glanzer, Koppenaal, and Nelson studies compared to the Glanzer and Meinzer study. This would be expected to result in an increased probability of items becoming unavailable in STS (Glanzer, 1972, p. 131) in the former studies. Further, not all searches will result in an item being added or reorganized within STS. Thus, any possible increase in the number of items in STS may well be offset by the fact that a search may not be rewarded. Consequently, there is no obvious theoretical need to find an increase in STS storage capacity in those studies having only a proportion of the list items related to other list items. Conversely, when a match is always accessible to the search process (when the second item is presented in a list constructed completely with related pairs), then any increase in STS storage may be effected since the other member of the designated pair could now be reorganized into a set with the present item. Clearly, the results of the research reported by Glanzer and his colleagues is at least supportive of the above hypothesis.

Glanzer suggested that Ss only enacted a different strategy when confronted with the Glanzer and Meinzer situation; the present proposal is that Ss used a different

strategy in all of the studies mentioned above. Utilization of a set of just 2 or 3 related items should provide the best possible test of Glanzer's hypothesis since it suffers the least from the problem of Ss using inappropriate strategies.

Wickens (1970, 1972) has recently argued in favour of the multiplicative and automatic nature of item coding. Essentially he is saying that many "attributes" of an item are coded upon a single presentation of the item and that this multiple encoding is effectively automatic. Underwood (1972) has suggested that automaticity of this process may be a misinterpreted artifact of attribute priming to the extent that any number of the attributes which Wickens finds to be effective in memory may only be due to the method of presentation. Wickens presents a series of items which may all be said to fall into a general class (or attribute). This, according to Underwood, may induce S to encode along that designated dimension when normally he might not. Essentially, this is the same problem we have been discussing above, albeit in different terms. The use of such a minimal degree of similarity in the present study, then, hopefully will avoid Ss becoming unduly primed on the phonemic attribute when it might normally be of somewhat less significance in coding.

DISTANCE AND STS

Another variable relevant to Glanzer's theory is that of distance. Distance between a given pair of list items is defined as the number of list items intervening between presentation of the first and second members of the designated pair. According to Glanzer, the distance between related items at presentation will determine the probability of their coexistence in STS. To the extent that a related pair coexist in STS, Ss "may make use of this relation in registering the pair in LTS" (Glanzer, 1972, p. 152), thus increasing the probability that both items will be recalled later. If the relation between the pair is used in registering each of the items in LTS, then each may serve as a recall cue for the other. Because the STS curves generally drop to near zero after 4 or 5 items (i.e., by using the Waugh and Norman correction formula for estimating the probability that item I was recalled from STS), Glanzer suggests that a distance of greater than 3 or 4 should be ineffective in producing a distance effect at the time of storage in LTS. It is also assumed that since similarity among items does not change the duration of an item's stay in STS (Glanzer, Koppenaal, and Nelson, 1972, p. 409), that the effect of distance on performance should be an inverse function of the distance. This is a direct result of the decreasing probability that the pair will be in STS together and, presumably, the diminishing amount of time the pair will be available in STS for transfer to LTS together. Glanzer's own work has demonstrated the effectiveness of

this variable both for semantic (Glanzer, 1969) and phonemic (Glanzer et al, 1972) similarity. The findings are generally supportive of the interpretation: recall of related items asymptotes at a distance of 2 to 3 items.

The present experiment endeavoured to replicate these findings using phonemic similarity. The distances used were 0, 1, 2, and 3 items.

In addition to replicating the phenomenon, another issue was considered which Glanzer does not deal with. If a given item is stored with a related item and each serves as a cue for retrieval of the other, then it would be expected that the clustering of related items in recall would be substantially above chance levels. This issue was also considered in the present study. It was referred to previously with regards to comparisons of the experimental and control groups. Presumably, both groups will demonstrate a significant degree of clustering in the present study. The clustering measure used was the stimulus category repetition (SCR) score suggested by Bousfield and Bousfield (1966).

ESTIMATING THE STS COMPONENT IN RECALL

One of the primary assumptions in Glanzer's hypotheses and arguments is the validity of the Waugh and Norman formula for estimating the STS component in recall. Due to its obvious significance, it would seem relevant to

investigate the application of the formula in some detail. Under close scrutiny, the procedure appears to have some problems which may be particularly relevant to the general model put forth by Glanzer and the research cited in support of the model. First, however, some basic background for the formula is necessary.

Waugh and Norman designed a probe recall experiment to provide a test between the decay and interference theories of loss of information from STM, or Primary Memory (PM), as they called it. Contrary to their expectations based on previous research, they found a near-zero probability of recall of an item if it occurred more than 11 items from the end of the list and also that the probability of recall was essentially independent of presentation rate. In attempting to account for these unexpected results, they developed a theoretical model which proposes that the probability of recalling an item from PM and Secondary Memory (SM) are independent. Thus, the probability that an item will be recalled from PM (Pi) may be defined as:

$$Pi = \frac{Ri - Si}{1 - Si} \tag{1}$$

where Ri is the probability that item _I_ will be recalled and Si is the probability that item _I_ will be recalled from SM. Ri is given by the empirical probability of recalling the _I_th item and Si is defined as the level of the asymptote of the SP curve. Essentially, then, this formula theoretically permits the extraction of the SM component from the PM component allowing one to arrive at an estimate of the PM

component independent of SM.

The authors subsequently reanalyzed previously reported data on the basis of the formula and found that they all provided estimates of Pi essentially equivalent to Waugh and Norman's own data. This was despite the apparent discrepancies between the data in the various reports.

Two principal problems with the formula seem evident, both resulting from the assumptions used to apply it and both very related. First, is the problem of using the asymptote of the SP curve to determine the LTS component of the recency portion of the curve. The basic assumption is that the asymptote carries through to the end of the list. Recent research dealing with "negative recency" (e.g., Craik, 1970) suggests that this assumption may be invalid. Craik used an immediate and final free recall test procedure in which a series of lists were presented with the study-test procedure. After all lists had been presented and tested in this manner, a final free recall test was given in which Ss were to attempt recall of as many items as they could from all the lists presented. The final free recall test showed that recall of the last few items (i.e., the "recency" items) actually drops below the level of the asymptote. If it is maintained that all items recalled from the final free recall test reflect storage in LTS, then it must be conceded that LTS storage of those last few items was poorer or more incomplete than that of earlier list items. Whatever the reasons for this may be (e.g., Watkins

and Watkins, 1974), it seems necessary to take it into account in the calculation of STS. If negative recency properly reflects storage in LTS of the recency items, then all calculations using the asymptote for estimating the LTS component will result in an underestimation of STS component. Although the resulting difference will usually be small, largely due to the typically small negative recency effect, it does seem sufficiently important to warrant consideration. Exactly this point has been raised recently by Watkins (1974, p. 703).

The second point is as theoretically important as the first but may prove quantitatively more significant. The recency portion of the list presented has always been defined as that which contains the STS component of recall. The primary assumption involved in this is that each list item which is presented will displace another item currently in STS, this process being essentially automatic. Glanzer maintains this assumption (1972, p. 130) and has provided evidence supporting the validity of the assumption (Glanzer et al, 1972). However, a somewhat more sensitive delineation of the STS component in recall would seem valuable. The major reason for this is that the assumption being made applies to all Ss across all lists which are presented. As a result of this massive generalization, it may be that an analysis which looks for any discrepancies or violations of the assumption will prove insensitive to them.

As a consequence, additional analyses were undertaken

in the present research. In addition to the Waugh and Norman formula, the Tulving and Colotla (1970; Craik, 1968) technique was also used. This procedure has been used recently by a few researchers interested in STS (e.g., Craik, Gardiner, and Watkins, 1970; Weist, 1972). This method of calculating the STS component necessitates a judgment of whether or not item I was recalled from STS by determining if n or less items (input plus output) intervened between the presentation and recall of I. The assumption behind it, then, is similar to the Waugh and Norman assumption: each item presented and registered in STS displaces another already there. Consequently, it also becomes subject to the same problems. But, to the extent that the specification of n reflects the capacity of STS, it might be expected that this procedure would provide results very similar to those obtained from the Waugh and Norman technique. It may be noted that both of these methods of calculation explicitly restrict what is in STS to the last few nominally presented items.

There may, however, be a third means of assessing the STS component, a method which can avoid the problems associated with the above two techniques. We noted previously that the overt rehearsal technique seems a reasonable and theoretically justifiable means of determining the contents of STS during the presentation of a list. It seems a small step from there to suggest that those items which are in STS immediately subsequent to the last item presented should form the basis of specifying

which items are recalled from STS. Those items which are recalled but were not in this final rehearsal set (RS), less the primacy items, may be assumed to provide the best estimate of recall from LTS. A necessary restriction on this estimate of LTS involves the final _m_ items presented where _m_ specifies the capacity of STS: recall of these particular items would not be included in the estimate of LTS even if they are not in the final RS. The problem involved is that these items will not have had the opportunity of being processed and stored in LTS since they will not have existed in STS for a long enough period of time. This may be the cause of the negative recency effect referred to earlier. It is likely then that these items would underestimate the probability of recall from LTS due to their decreased availability there. Although a similar situation may exist for selected other items in the list, it would seem to be a less general case than for the most recently presented items.

Watkins (1974) has dismissed this means of determining the capacity of STS on the grounds that "the size of the overt rehearsal set probably mirrors the number of primary memory items actually recallable rather than the potentially larger number in store at the time of the recall signal" (p. 700). Apparently, then, the only problem with this method of assessing Pi is that more items may actually be in STS but are not recalled because of the effects of output interference from other items which have previously been recalled from STS. If we permit the last RS to define the

items which are in STS at the time of recall, we are at worst underestimating Pi. It will be recalled, though, that many theoretical views of STS assume a direct and complete readout of the contents of STS. To what extent output interference can be said to offset recall of STS items must await future research.

The advantages of this method of determining the STS component in recall are threefold. First, it avoids the problem of being insensitive to Ss' efforts to actively manipulate what items will be maintained in STS: it does not assume that Ss react in a completely passive way to the input of items. Secondly, it permits the determination of which items are in STS at the time of recall not only as a function of each individual S but also as a function of each list presented to each S. This would seem an ideal situation and only requires the assumption that overt rehearsal reflects the contents of STS. Finally, it permits an accurate analysis of changes in the capacity of STS as a function of experimental manipulations. Specifically, with regards to the present research and the theoretical views being considered, we may assess whether phonemically related items do in fact remain in STS longer than unrelated items and whether this results in an increase in the number of items in STS or simply the selective filtering out from STS of very recently presented items. The latter situation might be expected to result in no overall change in the capacity of STS.

It may be noted in addition that this final technique permits the assumption made by others (Glanzer, 1972; Waugh and Norman, 1965) that an item may exist simultaneously in STS and LTS. But consequently, given that an items exists in both STS and LTS and given that it is recalled from STS, there is no need to apply a correction formula to the derived estimates of Pi. While a delayed or final free recall test may demonstrate that the item does exist in LTS, the immediate recall of the item from STS will be completely independent of its LTS trace. Thus, the present technique for estimating Pi will be unaffected by the estimate of Si.

The same argument could apply in the Waugh and Norman technique to the recall of items from STS. In other words, their concurrent existence in LTS, although it may initiate recall at a later time (e.g., after a delay task or in a final free recall test), has absolutely no effect on their immediate recall. On this basis, it seems somewhat illogical to use the LTS component in calculating the STS component. But although the theoretical issue is reasonably obvious, it must be conceded that there would be some difficulty in applying this modification to the use of the technique: there would be a need to assess exactly which items are being recalled from STS on a given trial and which come from LTS. This, of course, is exactly the reason that the correction formula was developed by Waugh and Norman. It would seem that the present approach of using those items which are in the final RS as reflecting the contents of STS could satisfy this problem.

The question which needs answering is what effect the above problem has on the results obtained using the Waugh and Norman formula. Clearly, it seems that if some of the items which are recalled from the asymptotic positions of the curve are actually being recalled from STS, then this will artifactually inflate the asymptote and, concurrently, the estimate of the LTS component. In the limiting case, where list recall is perfect, the estimate of Pi becomes zero. Watkins (1974) has correctly noted that any variable which increases the level of recall from LTS will also necessarily lead to an underestimation of Pi. Finally, Watkins has also pointed out that all items need not necessarily enter STS at the time of presentation (i.e., the transfer of information from sensory memory to STS is not "automatic"). "The fact that (the final list) item is not always recalled indicates that...not all presented items enter primary memory" (p. 703). This will again result in an underestimate of Pi. Watkins has failed to acknowledge, though, that this process will also result in a slight underestimation of LTS, although it is true that this cannot offset the underestimate of Pi to any appreciable extent. The operation of each of these factors, then, will serve to underestimate the STS component in recall if the Waugh and Norman formula is applied as suggested by them and by Glanzer (e.g., 1972).

In conclusion, then, the compelling assessment is that Glanzer's estimation of STS rests on faulty premises. For

comparative purposes, however, the present study will evaluate STS by each of the proposed methods.

In summary, the aim of the present investigation was twofold. First was the assessment of processing of phonemically related items in a free recall task. The second aim was to compare the various methods of calculating the capacity of STS. For the purpose of both of these issues, two independent groups were utilized. An experimental group received the succession of free recall lists with instructions to overtly rehearse the list during presentation. A control group received identical lists but they were only given standard free recall instructions. An overall comparison of the two groups on a number of measures determines the validity of generalizing inferences about the experimental group based on their overt rehearsal to the traditional free recall condition in which Ss do not overtly rehearse.

Of the 20 lists presented to all Ss, two were practice lists and sixteen were the critical lists containing either a single pair or a single triad of homophones. The remaining two lists contained no related items and were interspersed between the critical lists. The related items were positioned at distances of 0, 1, 2, or 3 items within the critical lists. As there were two levels of similarity and four distances, each S provided two replications in the factorial combination of the two variables.

METHOD

The present experiment was modelled largely after that of Glanzer, Koppenaal, and Nelson (1972). The phonemically related groups of items used here are essentially equivalent to their "C1" groups; the "C2" and "V" groups were not included.

Materials and Apparatus.

Two hundred and forty common monosyllabic English nouns, all 3-5 letters in length, were used to construct two practice lists and 18 test lists, each 12 items long. Of these 240 items, 200 were judged by E as "unrelated". Within each list, an attempt was made to maximize the degree of unrelatedness. The remaining 40 items constituted the related groups: 16 of these formed 8 groups of 2 items each; 24 formed 8 groups of 3 items each. These phonemically related items were rhymes, differing only in their first phoneme from the other member(s) of the group; these items were also orthographically identical, again, except for those letters making up the first phoneme. Neither of the practice lists (which were identical for all Ss in all conditions) contained any of the related items. Of the test lists, 2 contained no related items (R1), another 8 contained a group of 2 related items (R2), and the remaining 8 contained a group of 3 related items (R3). No list included more than one group of related items.

Two different orders of the lists (O1 and O2) were

used. For both orders, the membership of each list was identical although the placement of the related items varied. In addition, the order of presentation of the lists was randomly determined with the restriction that one of the R1 lists occurred in each half of the test lists.

Similar items within lists were arranged at distances of 0 (D0), 1 (D1), 2 (D2), and 3 (D3) items according to the patterns in Tables 1a (R2) and 1b (R3). Within each of O1 and O2, 2 levels within each distance were represented. The particular selection of which levels of each distance would be used in each order (see the rightmost column of Tables 1a and 1b) was determined with an attempt at distributing as equally as possible the occurrence of related items across all input serial positions (SP) within each level of O. Thus it was intended to place an equivalent number of related items in the first (primacy) and last (recency) portions of each order. The resulting arrangement left distance factorially combined with levels of R (i.e. R2 and R3) but the 3-way interaction of R x D x SP of similar items was partially confounded with Ss and orders. Ss and orders, of course, were completely confounded.

As was mentioned, membership in each individual list was identical across orders as was the ordering of the unrelated items; only the placement of the related items changed from O1 to O2. Once a given group of related items had been assigned to a list of unrelated items and the selection of the levels with each distance (L(D)) had been

made, two random orderings were made by which each list was assigned to a D x L(D) combination.

Typed lists were filmed with a 16mm Bolex movie camera and presented on an Audiscan screen. Ss sat approximately 2.75 feet (.838 m) from the display screen which itself was mounted within a large wooden screen so as to conceal both the equipment and the experimenter during the progress of the experiment. Recording of the Experimental Ss' overt rehearsals was done with a Sony tape recorder; the microphone was placed around the S's neck.

Procedure

Each S was tested individually. All Ss were initially read standard free recall (FR) instructions and told that a visual cue (a row of 3 asterisks) on the screen subsequent to the presentation of each list would be the signal to begin recall. The recall interval was 35 seconds. At the end of the recall interval, the same cue reappeared (accompanied simultaneously by an auditory transient) indicating that the next list was about to begin. Recall was written, with one page of the answer booklet allotted to each list (including the practice lists). Lines were provided on each page with one extra line (i.e., a total of 13 lines per page) occurring on each page. In addition, two extra pages (i.e., a total of 22 pages per booklet) were included in the answer booklet. Ss were not told how many items would be presented in each list nor how many lists

there would be in total.

The control group (C) received only the FR instructions. The experimental group (E) was further instructed to overtly rehearse the items during presentation of the list. Rehearsal was to be frequent and accurate and was intended to reflect that S was "thinking of a list word". During presentation of the practice lists, the experimenter reinstated the need for frequent and accurate rehearsal, as it was necessary for individual Ss. During overt rehearsal of either the practice lists or the test lists, the occasional S began generating sentences linking the items of the list. These Ss were immediately instructed to rehearse only those items which occurred in the list. As a consequence of this control exerted over the E group's rehearsal, it was deemed necessary to eliminate from the C group all Ss who used such a mnemonic device. At the end of the experiment, C Ss were asked specifically if they had endeavoured to remember the list by forming the items into sentences. No Ss reported using such a strategy and as a result none were dropped from the experiment.

Items were presented at a 5-second rate. The visual signal indicating the recall phase was also presented for a 5-second interval followed by a 30-second interval in which the screen was blank. The signal for the commencement of the next list was also presented for 5 seconds during which time S was instructed to turn the page of his answer booklet. The experiment lasted approximately 35 minutes.

Subjects

Forty undergraduates from the University of Alberta participated in the experiment for course credit. Subjects were assigned to the E or C conditions on the basis of a predetermined random ordering. Condition 01 was completed for both E and C groups prior to the running of condition 02.

RESULTS

Comparison of E and C groups.

It was noted that to maximize the generality of the results obtained from the E group, three sets of results should be comparable for the E and C groups.

The first comparison between the two groups was with respect to the shape of the serial position curves. The results are plotted in Fig. 1. Although there appears to be some tendency for the C group to perform better over most serial positions, this tendency was not borne out by analysis of variance ($F<1$). Similarily, O, groups x O, and groups x SP proved nonsignificant (all $F's<1$). Statistically, then, there were no differences in the E and C groups with respect to the serial position curve.

Secondly, total recall of related and total recall of unrelated items was compared over the two groups. The data are presented in Table 2 as a function of relatedness, number of related items in the list, and the distance between the related items. Analysis of variance on this data yielded no significant main effect due to groups ($F(1,96)=1.34$, $p>.05$). Further, the group variable did not interact with any other variable in the analysis (all $F's<1$). Clearly, then, recall performance was unaffected by requiring <u>S</u>s to overtly rehearse list items.

The final comparison between the C and E groups dealt

with the probability of pairwise recall of related items. To appropriately compare the two groups, a simple clustering measure was used. First, the number of opportunities to cluster related items (OPP) was defined by the total number of related items recalled by each S.

Secondly, the occurrences of clustering of these related items (OCC) was defined as the consecutive recall of related items. For example, when S recalled a total of two related items from a maximum of either two or three possible related items (defined by input) and these two items were recalled consecutively, S was scored as having OPP=2 and OCC=2. Similarily, if three related items were recalled, two of which were recalled consecutively and the third being recalled with a distance of greater than zero from both of the other related items, S was scored as having OPP=3 and OCC=2. The derived score was obtained by dividing the number of occurrences of clustering by the number of opportunities to cluster.

The data are presented in Table 3. No analysis of variance was performed on this data due to the contingency relationship between OCC=2 and OCC=3 under OPP=3. No clearcut differences are evident from this data, although there dces appear to be an increased tendency for a single pair of related items to be recalled consecutively by the C group compared to the E group when only two related items are recalled. As this trend does not carry through to OPP=3, it will be of no concern to us through the remainder

of this paper.

Further evidence to substantiate this essential lack of differences in clustering between the C and E groups is presented in Table 4. The measure of clustering used here was the Bousfield and Bousfield (1966) Stimulus Category Repetition (SCR) score. A negative value in this Table reflects an above chance level of clustering. Analysis of variance of these data[2] yielded no significant difference between the Control and Experimental groups ($F<1.0$). This group variable also did not interact with any other variables in the analysis (all p's$>.05$). Clearly, there are again no consistent differences between the two groups.

Effects of Similarity on Rehearsal and Storage

To assess the effects of similarity on rehearsal and storage as a function of number of similar items and the distance between similar items at input, a comparison was made between the similar items within lists (Ie) and those items in the identical serial positions at input in the two lists which each S received having no related items (Ic).

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[2] It should be noted that these clustering scores were derived by designating all unrelated items recalled as a single "category". To avoid the possible problem of these unrelated items being the direct cause of the above chance level of clustering, a second analysis was run in which each unrelated item recalled was designated as a distinct "category". The results of the analysis were identical to the first with the single exception of a significant G x R x D interaction ($F(3,108)=4.06$, $p<.01$). Inspection of the data suggests this interaction to be primarily a function of a relatively high degree of clustering by the Control group at D3 accompanied by a certain amount of variability across the other levels of D.

These comparisons were made on a number of different dependent measures. The first three of these measures, S-WORD, N-WORD, and S-ISR, were taken directly from Kemler and Weist (1974). A fourth measure used here was a modification of another measure from Kemler and Weist; specifically, I-OSR. The modification used here may simply be termed OSR.

S-WORD

The S-WORD measure reflects the absolute number of rehearsals allotted to each given item in the input list. The data are presented in Tables 5a and 5b for R2 and R3 respectively. Separate analyses of variance were carried out on these two sets of data, necessitated of course by the different number of serial positions within the related groups of items (P). However, the results for S-WORD were identical for both sets of data and thus will be presented together in this analysis. The main effects of O, D and I proved nonsignificant (all p's>.05) however the main effect of P was highly significant (both p's<.01). (P1 represents the first, P2 the second, and P3 the third of the related items presented.) The 2-way interactions of O x D and D x P attained significance for both R conditions (all p's<.01); all other 2-way interactions were nonsignificant (all p's>.05). Also the 3-way interactions of O x D x P reached significance for R2 and R3 (both p's<.01). None of the other 3-way interactions nor the 4-way interaction proved significant.

The statistically significant main effect of P is of little theoretical interest here as it simply mirrors the fact that the earlier an item occurs in the input sequence, the greater the number of rehearsals it will receive. Obviously the D x P interaction simply magnifies this effect. The O x D and the O x D x P interactions are essentially a result of serial position in the input sequence being a nested variable with respect to each of the levels of D, and thus are also of little theoretical interest.

The variable which is of greatest concern to us is I. Clearly there was absolutely no effect on the S-WORD measure as a result of the similarity manipulations: Ss did not tend to alter the absolute number of rehearsals given to items when they were phonemically related (Ie) as compared to the control (Ic) items. Also, this variable did not interact with any other variable. The theoretical relevance of these findings will be dealt with in the DISCUSSION section of the paper.

N-WORD

The second dependent measure analyzed was N-WORD. This measure refers to the normalized number of overt rehearsals allotted to a given item and is defined for a given item as:

$$\text{N-WORD} = \frac{\text{S-WORD}}{\text{TOTAL NUMBER OF REHEARSALS OF ALL ITEMS IN THAT LIST}} \times 1000 \qquad (2)$$

The data are presented in Tables 6a and 6b for R2 and R3

respectively.

For condition R2, all effects replicated those of the S-WORD analysis. Thus, the effects of P, O x D, D x P, and O x D x P all reached significance (all p's$<.01$). For R3, again the effects of P, O x D, and D x P were highly significant (all p's$<.01$) while marginal significance was found for O x D x P ($F(3,54)=2.94$, $p<.05$) and O x D x I ($F(3,54)=3.18$, $p<.05$).

The remarks put forth in the S-WORD analysis with respect to each of these effects are again relevant for the N-WORD analysis.

While no other effects were significant in R2 (all p's$>.05$), marginal significance was found in R3 for the main effect of I ($F(2,18)=5.38$, $p<.05$). This reflects the slight increase in the normalized number of rehearsals given to Ie items (84.84) compared to Ic (80.31). This increase is approximately 5.6% and must be considered minimal.

S-ISR

The third dependent measure of interest was the relative number of pairwise rehearsals of the related items (Ie) compared to the control items (Ic). For R3, there are three possible combinations of these pairwise rehearsals: P1P2 or P2P1; P1P3 or P3P1; P2P3 or P3P2. These combinations will be referred to as T1, T2, and T3 respectively. For R2, of course, only T1 can occur and thus

the variable drops out of the analysis.

The data are presented in Tables 7a and 7b. Analysis of the S-ISR data for R2 yielded highly significant effects of D, I, and O x D (all p's<.01). D x I was marginally significant ($F(3,54)=3.11$, $p<.05$) but all other effects were nonsignificant (all F's<1).

For R3, all of the effects which were significant in R2 were again significant in R3 (all p's<.01). D x I, which was marginally significant in R2, was highly significant in R3 ($F(3,54)=4.42$, $p<.01$). In addition the main effect of T and the interactions of D x T and O x D x T were all significant (all p's<.01). The interaction I x T was marginally significant ($F(2,36)=4.22$, $p<.05$).

These results may be summarized as follows. First, the main effects of D essentially reflect the substantial difference in the number of S-ISR's for D(0) relative to all other distances.

The main effects of I statistically confirm the finding of the large increase in the number of S-ISR's for Ie compared to Ic. For R2, this increase was approximately 75% and for R3 approximately 81%. Thus, Ss were very prone to grouping related items during rehearsal in comparison to unrelated items in similar input serial positions. The interactions of D x I are primarily a function of the differences for D(0) and to a lesser extent D(1) being subjected to a floor effect in D(2) and D(3). This is not

unexpected on the basis of the previously reported effects of Distance and the theoretical significance which Glanzer attaches to it. In addition, of course, the main effects of D and T are again confounded with input serial position as are the interactions O x D, D x T, and O x D x T.

Also, the main effect of T is related to the finding that Ss tended to rehearse the pairs T1 and T3 rather than T2, indicating simply that they maintained the order of input of the related items during rehearsal. Alternatively, at a theoretical level, this effect may be interpreted as evidence that there is a decreasing probability that a given pair of items will be in STS together as the distance between the pair at input increases. Thus, since the distance between P1 and P2 and between P2 and P3 will always be less than the distance between P1 and P3, we might well predict this main effect of T. All other effects were nonsignificant (all p's$>.05$).

OSR

The OSR measure is defined as the pairwise occurrence of items in the recall protocol. It differs from the Kemler and Weist measure, I-OSR, in that it is not contingent upon the pairwise occurrence of the items in rehearsal. This modification of the I-OSR measure was adopted due to an uncertainty about whether Ss always output, as an overt rehearsal, each item to which he is attending (i.e., each item which is in STS). If it is the case that Ss do not

always verbalize what they are covertly rehearsing, then the I-OSR measure would prove a conservative measure. Consequently, nonsignificant differences as a function of I-OSR may only reflect a baseline effect. It will be appreciated that in fact a baseline effect is already working on the OSR measure when recall is less than perfect. (The mean OSR for R2 and R3 was 0.22 and 0.16 respectively.) In addition, certain criticisms have been raised with respect to dependency measures (see Runquist, 1974). To investigate more closely the relationship of S-ISR to OSR, a correlation was run between the number of S-ISR's for a given pair of words and the observed probability of pairwise recall of those words. This will be reported below.

The data are presented in Tables 8a and 8b. For R2, significant main effects were found for D and I (both p's$<.01$). A marginally significant interaction was found for O x D ($F(3,54)=4.00$, $p<.05$). No other effects were significant.

In R3, the main effects of D, T, and I were all highly significant as were the interactions D x I and T x I (all p's$<.01$). Further, marginal significance was attained for the interactions O x D and D x T (both p's$<.05$). No other effects were significant.

The main effects of D for the OSR measure will be dealt with in the DISCUSSION. It is sufficient to note here that D is no longer artifactually related to input serial position in a direct way as we are now dealing with recall

rather than rehearsal. Thus, a main effect of D for OSR must reflect storage and/or retrieval differences.

The main effects of I substantiate the readily apparent differences between the two groups. For both R2 and R3, the number of OSR's for Ie exceeded those of Ic by more than 185%. Clearly, there was a marked increase in the probability of the related items being recalled in a pairwise manner relative to the control items. The finding of an interaction of D x I supports the observation that the large differences between Ie and Ic in OSR for D(0) decreased dramatically at the greater distances. Interestingly enough, this finding was not replicated by the analysis of OSR for R2, although the trend is in the same direction. Why the statistical interaction occurs in R3 but not R2 is unclear at present, however at the same time it is likely not a critical issue.

The main effect of T for R3, as in the S-ISR data, reflects the finding that the pairs tended to be output in the same order as they were presented. The occurrences of events T1 and T3 in recall were more than 115% greater than T2. The major contributor to the T x I and D x T interactions was also T2, primarily due to floor effects operating in Ic.

Relationship between S-ISR and OSR

Correlations were calculated between the number of S-ISR's accorded each of the possible pairs of related items

and the observed probability of pairwise recall of each of these pairs. For R2 and R3, the correlations were significantly positive ($r=+0.6582$, $r=+0.5484$ respectively, both $p's<.01$). Essentially, these correlations mean that the probability of pairwise recall of a given pair of items was directly related to the number of rehearsals allotted to the pair.

Estimates of Pi

Three different estimates of Pi were taken. The first two, those proposed by Waugh and Norman and by Tulving and Colotla, are highly related to the extent that both permit only the nominally-defined recency items to enter into the estimate. It was noted earlier that, as a consequence, the two may reasonably be expected to yield highly similar values for Pi. The third estimate of Pi developed herein defines the contents of STS at the time of recall as those items in the final RS.

The derived values are shown in Table 9 as a function of the method of calculation and conditions E and C. Note, of course, that no estimate may be arrived at for the C *S*s using the third method of calculation. The Waugh and Norman estimates were based on the final 5 input serial positions and positions 4, 5, 6, and 7 were used to estimate Si. In calculating Pi using the Waugh and Norman formula, only positive values for a given serial position are computed into the estimate: negative values do not affect the

estimate. All values shown represent Pi values averaged over all Ss.

No statistical analyses were carried out on this data for a number of reasons, primarily the fact of the missing data for the C group under the third method of calculation. The results, however, are clear: both the Waugh and Norman and the Tulving and Colotla methods of calculating Pi yielded substantially smaller estimates than the third method based on the contents of the final RS. The comparatively low values of Pi are discussed below.

The Waugh and Norman estimates, it will be recalled, were based upon the final 5 input serial positions. The obtained values are highly similar to those obtained with the Tulving and Colotla method with i=5.

DISCUSSION

The two general purposes of the present research were to investigate the fate of phonemically related items in STS under the auspices of the overt rehearsal method and to make comparisons between the different methods of calculating the capacity of STS. A number of results are relevant to each of these matters.

With regard to the first issue, it has been noted that many dual process theories posit a relatively passive role for STS: that is, items enter STS rather automatically upon presentation and if rehearsed will remain in STS until displaced by a newly-arriving item. The results of the present study do not permit the denial of this aspect of the passive role allocated STS: the S-WORD and the N-WORD analyses both showed no consistent effect due to the critical items (Ie) of the lists. This conclusion is further substantiated by the failure to observe any obvious increase in the occurrence of the related items in the final RS relative to unrelated items from similar input serial positions. To investigate further this particular feature of the data, it would appear necessary to include additional lists which have no related items so as to allow an increase in stability of the base measure against which to compare the critical items. However, with regard to the organization of items within STS, clear evidence is available from the S-ISR data that pairwise relationships among items will result in the regrouping of these items in

STS. This regrouping appears to increase the probability that these items will be recalled at output (Table 2) and further, based on the OSR data, that they will be recalled in a pairwise manner. The fact of this apparent reorganization within STS solves the earlier criticism of the Glanzer et al (1972) study which concluded that no increase in length of stay in STS is effected by reorganization. The problem with this conclusion was that no measure of reorganization in STS was taken and consequently no strong theoretical conclusions may be drawn regarding the effect of reorganization.

The overall impression to be gained from these results is that relationships among words lead to their being reorganized into groups in STS and that in some way this results in an increase in either the "availability" or the "accessibility" (Tulving and Pearlstone, 1966) of these items in LTS. On the basis of an earlier suggestion that overt rehearsal of an item reflects the possibility that an item is being processed, it would appear that storage of the related items is in no sense greater than that of the related items as the the number of rehearsals, either absolute or normalized, were not different. Similar effects have recently been reported by Einstein et al (1974). They found that a distinctive item in the list was recalled better than the remaining list items (the von Restorff effect) despite the fact that this item received no more overt rehearsals than the other items. The implication is that the distinctive attributes of the isolated item are

sufficient of their own accord to result in better retrieval. Similarily, it may be that the accessibility or the retrievability of related items is enhanced relative to unrelated items strictly as a function of their distinctiveness. This particular aspect of the data may be interpreted in light of Baddeley's (1972) discussion of retrieval rules. While it may be argued that all list items must have a retrieval rule of some variety so that they may be accessed at all, it may also be the case that presentation of a group of related items will lead to the related attribute becoming an increasingly potent retrieval rule. This may be viewed as simply a generalized version of frequency theory (Ekstrand, Wallace, and Underwood, 1966) with respect to attributes but is also no dissimilar to Weist's (1972) conception of "working memory" discussed previously.

With respect to Glanzer's model of memory outlined above in some detail, the present results must be viewed as favourable. Glanzer predicts the lack of effects of the similarity manipulation on the S-WORD variable by means of his assumption that items will be displaced from STS rather automatically by newly-arriving items and thus the length of stay of each item is essentially independent of item-to-item relationships. This effect replicates those reported by Glanzer et al (1972).

Certain other aspects of Glanzer's hypotheses have also received support from the present data. The distance effect

demonstrated by Glanzer (1969) and Glanzer et al (1972) was interpreted as evidence that items which do not coexist in STS will not have the opportunity of being stored together in LTS. At an empirical level, this would be reflected by an inverse relationship between the distance of the related items at input and the observed probability of their pairwise recall. The distance effect was replicated in the present study. That this effect is rooted in the encoding stage and not strictly the retrieval stage of learning may be suggested by the fact that the distance variable proved to be a highly significant factor in the S-ISR data also.

It is of interest to note that Glanzer's interpretation of the distance effect as reflecting whether or not the relationship among items has been stored in LTS is a viable explanation of the effects of blocked versus randomized presentation of categorized lists. Specifically, clustering and recall tend to be greater under the blocked versus randomized orders (e.g., Cofer, Bruce, and Reicher, 1966). The alternative forms of presentation may be seen as simply a manipulation of distance. The greater the distance between related items, the less will be the time that they coexist in STS and consequently the less the overall probability that they will be registered together in LTS.

On the basis of the present interpretation of overt rehearsal, clear evidence has been found showing that items may be reorganized within STS consistent with Glanzer's interpretation of mnemonic structures being developed within

STS. However, no evidence is forthcoming to substantiate the further assertion that this restructuring of the contents of STS will lead to their stay in STS being prolonged. Again, this is consistent with the Glanzer et al (1972) study.

Deleting this hypothesis from Glanzer's theory in fact makes the model much more parsimonious than originally outlined (Glanzer, 1972). Specifically, it was stated that "all verbal items entering the system remove items from STS. The specific characteristics of the items play no role - their difficulty, length, and similarity to list items" (Glanzer, 1972, p. 148). This is apparently in contrast with the later statement that "the setting up of mnemonic structures may result in a reorganization that helps maintain items in STS" (p. 149). A model which posits that neither the characteristics of the incoming items or the already-stored items affect what will be added to STS and what will be deleted is also consistent with the present data. Again, the Einstein et al (1974) data on the von Restorff effect may be cited in support of such an interpretation of item replacement in STS.

Certain additional aspects of the present research require brief consideration. First, the failure to find consistent appreciable differences between the C and E groups on the various measures permits a certain degree of confidence in generalizing from the overt rehearsal Ss to those Ss given normal study conditions (i.e., silent study).

It does not seem unreasonable to assume essentially identical processing in the two groups on the basis of the present data. A number of previous reports have shown a decline in overall recall performance as a function of overt rehearsal conditions (e.g., Jacoby, 1973). These results need not be seen as reflecting differential types of processing but probably only demonstrate that overt rehearsal itself takes away a certain amount of processing time from generally all items. Thus, it is likely the degree of processing accomplished rather than the actual type of processing which differentiates the C and E groups on the recall measure.

A second aspect of the present research involves a comparison with the traditional free recall literature. Few previous studies have utilized a study interval greater than 2 seconds per item whereas the present research utilizes a study interval of 5 seconds per item. There is no obvious reason why this manipulation should be seen as limiting the generality of the present data since again the difference will likely result only in a quantitative and not a qualitative discrepancy in item processing. Obviously this increase in processing time for items directly relates to the relatively high level of recall performance of the prerecency items (i.e., recall from LTS) and consequently poses no real problem for the essential argument offerred herein.

MEASUREMENT OF STS

The second primary focus of the present paper was the measurement and capacity of STS. Each of the critical theoretical arguments have been outlined earlier. Consequently, we shall restrict the present comments to consideration of the results.

The most apparent finding when observing the estimates of Pi shown in Table 9 is the fact of the extremely low values obtained, especially for the Waugh and Norman and the Tulving and Colotla methods of calculation. Although initially astounding, these results are not unpredicted. Earlier, it was noted that any variable which increases the level of recall from LTS will result in an underestimate of Pi based on the Waugh and Norman calculation (Watkins, 1974). In fact, the relatively slow rate of presentation (5 sec/item) did result in an increased estimate of Si compared to the traditional faster rates of presentation (e.g., 2 sec/item). Although Watkins' own analyses do not demonstrate a decline in the estimate of Pi with this variable for either method of calculation (see his Table 1), no estimate of Si is presented. Consequently, we have no knowledge of whether differences in Si were actually obtained from which to evaluate the argument. These values in the present experiment were 0.549 for the C group and 0.521 for the E group using the Waugh and Norman analysis. Using the Tulving and Colotla (1970) method, the estimates of Si were 0.513 and 0.498 for the C and E groups

respectively with a lag value of 5. All of these values are based on nonprimacy list positions. These values are exceptionally high compared to the more generally found Si values of approximately 0.200 to 0.300 (e.g., Watkins and Watkins, 1974) and thus lead to the conclusion that Pi as a result was substantially underestimated by these methods of calculation. Additional evidence has recently been forthcoming on this issue. Relatively low estimates of Pi were obtained by Glanzer and Razel (1974; Expt. 4) when they increased the presentation time of individual words from 1 sec/word to 4 sec/word. The drop in Pi was one full item (2.9 to 1.9).

In comparing the third method of calculation to the others, a clear increase in the estimate of Pi is evident. The reasons why this particular result is also not unexpected hinge on the notions that items which are recalled directly from STS are not necessarily restricted to the nominal recency positions of the list and that correcting the estimate of Pi for probability of recall from LTS is inappropriate when the contents of STS can be assessed. Each of these arguments was discussed at length previously and so will not be repeated here. In addition to these, it will be noted that on mathematical grounds, there is no reason to believe that an increase in Si will directly result in a decline in the estimate of Pi, as is the case for the Waugh and Norman method. This does not negate the possibility that any given experimental manipulation itself may lead to a decline in the estimate of Pi purely as a

function of the workings of the memorial system.

As Watkins (1974) has said, use of the last RS to assess the contents of STS will itself underestimate Pi primarily as a result of output interference. (Watkins' own statement of this problem (see p. 36) may offer an acceptable interpretation of Glanzer's remarks about an item in STS becoming "unavailable".) If in fact output interference is operative in STS, then it will be the case that the strict "read-out" description of recall from STS is inappropriate under conditions of recall and further that all estimates of Pi based on recall performance will be underestimates of the capacity of STS.

The estimate of Pi with this final method is based on recall of the contents of the final RS. In a minimal attempt to offset effects of output interference on Pi, we consider the size of the last RS itself relative to the estimate reported. Recall performance gives Pi a value of 3.13 whereas the average number of different items in the final RS increases this value to 3.47. Since rehearsal itself must be viewed as a form of output and consequently is likely also subject to output interference, even this latter value of Pi probably is an underestimate of the true value of Pi. It is not readily apparent how the problem of output interference can be offset to permit an accurate estimate of Pi using this or any other method of calculation.

Finally, it will be recalled that we earlier noted a

further suggestion by Watkins regarding the assumption that items entering the sensory system automatically enter STS. Watkins' criticism of this assumption was based on the often observed fact that the final list item is not always recalled even on an immediate test. To evaluate the extent to which this is the case, we determined the number of times the final list item was not rehearsed, the number of times it was not recalled, and the number of times it was neither rehearsed nor recalled. The resulting values were 16.22%, 33.89%, and 8.33% respectively. Although the number of times the item was not recalled (33.89%) is the appropriate figure based on Watkins' argument, the best value to use is obviously the final one (8.33%) if we wish to best estimate the probability that the final list item never entered STS at all. Even this value must be considered an overestimate since some Ss apparently utilized a strategy whereby they attempted to maintain the item at a level of processing prior to that where it could be overtly rehearsed (possibly so as not to overload STS) and then attempted to bring it to the level of processing necessary to output it only at the time of the recall test. That the item was not always available at the time of recall may reflect the loss of it from a more peripheral memory system which is more susceptible to very rapid decay (Sperling, 1960). Given the large difference between the number of times the item in SP 12 was not rehearsed and the number of times it was neither rehearsed nor recalled, there may be some real problem in assessing the effect on Si of items not entering STS.

Possibly the best way of assessing this is to calculate the number of times the last item presented in a list is neither rehearsed nor recalled when list length varies randomly as a within-subject variable. This will presumably avoid the problem of Ss activating undetermined strategies for storing the final list item given that they know that the particular item is in fact the final item of the current list.

SUMMARY

With regard to Glanzer's theory of memory, the following comments are relevant. There was clear evidence reported showing that *S*s reorganize the contents of STS during the presentation interval and that this reorganization appears to have been directly related to the output protocols. At the same time, however, this reorganization evidently did not result in the related items being rehearsed more or retained longer in STS, although a suggestion was made as to how the latter issue might be investigated more thoroughly.

The calculation of the capacity of STS was also of primary interest. Based on the assumptions about overt rehearsal expressed herein, it is clear that differences in the estimates of Pi are substantial according to the method of calculation used. A number of confounds were indicated as affecting the traditional means of determining the capacity of STS but these confounds were minimized when the final rehearsal set is used to determine the contents of STS at the time of recall.

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TABLE 1a

Serial Position of Similar Items in Condition R2

D	L(D)	1	2	3	4	5	6	7	8	9	10	11	12	O
0	A		X	X										1
	B					X	X							2
	C							X	X					1
	D										X	X		2
1	A	X		X										2
	B				X		X							1
	C							X		X				1
	D										X		X	2
2	A	X			X									2
	B			X			X							1
	C							X			X			2
	D									X			X	1
3	A	X				X								1
	B			X				X						2
	C						X				X			2
	D								X				X	1

TABLE 1b

Serial Position of Similar Items in Condition R3

D	L(D)	Serial Position												O
		1	2	3	4	5	6	7	8	9	10	11	12	
0	A	X	X	X										2
	B				X	X	X							1
	C							X	X	X				1
	D										X	X	X	2
1	A	X		X		X								1
	B		X		X		X							2
	C							X		X		X		1
	D								X		X		X	2
2	A	X			X			X						1
	B		X			X			X					2
	C						X			X			X	2
	D					X			X			X		1
3	A	X				X				X				2
	B		X				X				X			1
	C			X				X				X		2
	D				X				X				X	1

TABLE 2

Recall of Related and Unrelated Items

as a Function of Groups, R, and Distance

RELATED

		E				C	
		R1	R2	R3	R1	R2	R3
D	0	---	.7250	.8417	---	.8625	.8167
	1	---	.6500	.7167	---	.6500	.6750
	2	---	.6750	.6584	---	.7375	.5917
	3	---	.6000	.5750	---	.6125	.7167

UNRELATED

		E				C	
		R1	R2	R3	R1	R2	R3
D	0	.5583	.6100	.5750	.6375	.6250	.5945
	1	---	.6000	.6000	---	.6475	.6000
	2	---	.5800	.5889	---	.6375	.5861
	3	---	.6175	.6306	---	.6250	.6316

TABLE 3

Percent Clustering in Recall When 2 (OPP=2) or 3 (OPP=3) Related Items are Recalled and 2 (OCC=2) or 3 (OCC=3) of These Related Items are Recalled Consecutively

		E		C	
		01	02	01	02
OPP=2	OCC=2	57.1	58.4	67.2	61.0
OPP=3	OCC=2	26.1	25.8	20.0	17.1
	OCC=3	60.9	61.3	63.3	60.0

TABLE 4

Clustering in Recall as Measured by the Simulus Category Repetition (SCR) Score of Bousfield and Bousfield (1966)

		DISTANCE			
		0	1	2	3
C	R2	-30.613	- 4.555	-13.402	- 5.293
	R3	-62.984	-23.316	-10.679	- 6.952
E	R2	-20.414	-10.433	- 8.680	- 7.759
	R3	-62.531	-25.163	- 0.905	+ 4.754

(NOTE: A negative value reflects a greater than chance level of clustering)

TABLE 5a

Mean Absolute Number of Rehearsals (S-WORD) as a Function of Order (O), Item (I), Relative Position of Related Items (P), and Distance of Related Items (D) in Condition R2

		O1				O2			
		Ie		Ic		Ie		Ic	
		P1	P2	P1	P2	P1	P2	P1	P2
D	0	6.75	5.60	6.20	4.50	3.90	3.10	3.65	3.20
	1	4.85	3.10	4.03	3.10	6.20	3.45	6.53	3.60
	2	4.00	2.10	4.63	2.53	7.70	3.75	7.25	3.40
	3	7.30	2.63	6.18	3.00	5.25	3.20	4.93	3.43
MEAN		5.73	3.38	5.26	3.28	5.76	3.38	5.59	3.41

TABLE 5b

Mean Absolute Number of Rehearsals (S-WORD) as a Function of Order (O), Item (I), Relative Position of Related Items (P), and Distance of Related Items in Condition R3

O1

		Ie			Ic		
		P1	P2	P3	P1	P2	P3
D	0	5.55	4.10	3.45	4.00	3.45	3.10
	1	6.80	5.30	3.25	6.48	4.73	3.40
	2	8.65	4.90	2.55	7.38	3.73	2.50
	3	7.30	3.40	1.45	7.40	2.98	1.88
	MEAN	7.08	4.43	2.68	6.32	3.72	2.72

O2

		Ie			Ic		
		P1	P2	P3	P1	P2	P3
D	0	6.45	4.75	3.10	6.58	4.93	3.60
	1	6.05	4.05	2.95	5.63	3.30	2.93
	2	6.35	3.85	3.20	5.98	4.10	2.58
	3	7.80	3.85	2.50	8.03	4.38	2.88
	MEAN	6.66	4.13	2.94	6.56	4.18	3.00

TABLE 6a

Mean Normalized Number of Rehearsals (N-WORD) as a Function of Order (O), Item (I), Relative Position of Related Items (P), and Distance of Related Items (D) in Condition R2

O1

		Ie		Ic	
		P1	P2	P1	P2
D	0	113.61	97.60	118.16	83.12
	1	85.91	53.47	74.92	60.35
	2	77.92	41.20	84.74	49.22
	3	127.20	47.55	108.20	55.50
MEAN		101.16	59.96	96.51	62.05

O2

		Ie		Ic	
		P1	P2	P1	P2
D	0	76.34	59.54	66.83	62.11
	1	119.13	66.85	118.08	66.22
	2	190.38	70.12	113.61	61.97
	3	99.55	65.29	91.77	61.86
MEAN		121.35	65.45	97.57	63.04

TABLE 6b

Mean Normalized Number of Rehearsals (N-WORD) as a Function of Order (O), Item (I), Relative Position of Related Items (P), and Distance of Related Items (D) in Condition R3

O1

		Ie			Ic		
		P1	P2	P3	P1	P2	P3
D	0	104.44	78.23	67.02	75.27	63.60	59.47
	1	114.07	90.44	55.94	116.41	84.74	63.00
	2	135.51	84.74	55.67	129.31	68.21	47.80
	3	134.14	63.57	24.95	135.15	57.35	37.17
MEAN		122.04	79.25	50.90	114.04	68.48	51.86

O2

		Ie			Ic		
		P1	P2	P3	P1	P2	P3
D	0	125.06	92.03	59.99	117.80	90.63	65.77
	1	116.87	75.83	57.24	103.32	57.99	57.06
	2	116.56	70.35	58.52	111.40	75.48	49.12
	3	138.11	69.69	47.13	133.94	76.60	50.95
MEAN		124.15	79.98	55.72	116.62	75.27	55.73

TABLE 7a

Mean Number of Pairwise Rehearsals (S-ISR) of Related Items in Condition R2 as a Function of Order (O), Item (I), Designation of Pairs (T), and Distance (D)

		O1		O2	
		Ie T1	Ic T1	Ie T1	Ic T1
D	0	5.05	3.28	2.65	1.33
	1	0.75	0.25	1.70	1.30
	2	0.45	0.33	1.25	0.55
	3	0.65	0.40	0.90	0.15
	MEAN	1.73	1.07	1.63	0.83

TABLE 7b

Mean Number of Pairwise Rehearsals (S-ISR) of Related Items in Condition R3 as a Function of Order (O), Item (I), Designation of Pairs (T), and Distance (D)

O1

		Ie			Ic		
		T1	T2	T3	T1	T2	T3
D	0	2.90	1.00	2.15	1.65	0.28	1.38
	1	2.55	0.70	1.25	0.68	0.40	0.53
	2	0.95	0.30	0.50	0.68	0.30	0.08
	3	0.65	0.25	0.20	0.25	0.08	0.13
MEAN		1.76	0.56	1.03	0.81	0.26	0.53

O2

		Ie			Ic		
		T1	T2	T3	T1	T2	T3
D	0	4.90	1.00	2.35	3.73	1.30	2.33
	1	1.30	1.05	0.85	0.55	0.15	0.40
	2	0.55	0.65	0.45	0.23	0.08	0.20
	3	0.45	0.15	0.00	0.53	0.20	0.18
MEAN		1.80	0.71	0.91	1.26	0.43	0.78

TABLE 8a

Mean Proportion of Pairwise Outputs (OSR) of Related Items in R2 as Function of Order (O), Item (I), Designation of Pairs (T), and Distance (D)

		O1		O2	
		Ie T1	Ic T1	Ie T1	Ic T1
D	0	.700	.325	.500	.225
	1	.100	.050	.450	.125
	2	.150	.030	.400	.100
	3	.150	.050	.200	.030
MEAN		.275	.114	.388	.120

TABLE 8b

Mean Proportion of Pairwise Outputs (OSR) of Related Items in R3 as a Function of Order (O), Item (I), Designation of Pairs (T), and Distance (D)

O1

		Ie T1	Ie T2	Ie T3	Ic T1	Ic T2	Ic T3
D	0	.700	.250	.450	.125	.050	.075
	1	.300	.050	.300	.125	.025	.075
	2	.200	.050	.200	.075	.050	.050
	3	.100	.100	.100	.025	.025	.050
MEAN		.325	.113	.263	.088	.038	.063

O2

		Ie T1	Ie T2	Ie T3	Ic T1	Ic T2	Ic T3
D	0	.550	.300	.700	.250	.125	.325
	1	.350	.250	.400	.075	.100	.050
	2	.100	.050	.150	.025	.025	.100
	3	.100	.050	.050	.025	.075	.075
MEAN		.275	.163	.325	.094	.081	.138

TABLE 9

Summary Table of Estimates of Pi Based of Three Techniques for the Control (C) and Experimental (E) Groups

TECHNIQUE	C	E
Waugh and Norman	1.42	1.55
Tulving and Colotla		
i=3	0.97	0.89
i=5	1.55	1.37
i=7	2.34	2.16
Final RS	----	3.13

TABLE 10a

Number of Occurrences of List Items in the Final Rehearsal Set as a Function of Input Serial Position of Items and List (L) for Condition 01

Serial Position

L	1	2	3	4	5	6	7	8	9	10	11	12
1	3*	3	0	3	3*	3	1	2	1	7	6	9
2	3	3	1	1	0	0	1	1	4	6	8	10
3	0*	2	1	1*	0	1	2*	3	4	3	7	9
4	3	3	1	4*	2*	1*	0	0	1	2	5	6
5	3	2*	1	0	0	1*	3	2	2	3*	6	9
6	2	3	3	3	2	2	1*	2	2*	3	4	7
7	3	1	2	1	1	2	3*	5*	0	2	5	9
8	1	1	2	1	3*	6	3	4*	3	7	7*	10
9	4	4	3	3*	3	2*	0	0	2	5	6	7
10	3	4	1	1	0	3	1*	0	4*	3	5*	10
11	1	2	3	0	0	1	4*	5*	4*	5	5	9
12	1	2	3	2	1	1	3	3	2*	1	4	10*
13	2	4*	4*	0	0	2	3	3	4	4	5	10
14	2*	0	2*	2	3*	2	1	1	1	5	7	10
15	2	0	1*	0	1	0*	2	2	5	4	6	7
16	1	4	1	3	1	1	0	0	3	4	3	9
17	0	2	1	3*	0	2	2	4*	5	3	4	8*
18	1	0	2	2	1	1	2	3*	4	3	6	10*

* - denotes critical items (Ie)

(NOTE: maximum value per cell = 10)

TABLE 10b

Number of Occurrences of List Items in the Final Rehearsal Set as a Function of Input Serial Position of Items and List (L) for Condition 02

		Serial Position											
		1	2	3	4	5	6	7	8	9	10	11	12
	1	0*	0*	0*	3	0	0	1	1	7	4	5	10
	2	1	2	1	2	1	1	3	2	3	4*	6	10*
	3	4	1	0	1	1	0	1	1	2	1	5	10
	4	1*	1	0	1	2*	2	3	2	2	3	5	9
	5	1	0	0	0	1	0	0	5*	9	6*	8	10*
	6	2*	1	0	1*	2	0	2	3	3	9	7	9
	7	3*	3	1*	0	2	0	2	3	2	4	5	9
	8	3	1	0	0	0	3*	1	2	4*	3	6	10*
L	9	1	0	0	0	1	2*	0	1	3	3*	8	10
	10	3	2	1*	1	0	2	1*	2	5	6	6*	10
	11	1	1	1	0	2*	0*	2	2	4	6	6	10
	12	0	1*	1	3	2*	2	3	4*	3	6	7	8
	13	2	0	2	1	2	2	1*	1	1	1*	7	10
	14	2	2	1	0	0	1	2	1	3	4	7	10
	15	0	0	1*	3	0	2	1*	3	3	5	5	10
	16	1	1*	0	2*	1	2*	5	3	6	5	7	9
	17	1	1	2	1	0	0	0	1	2	6*	9*	9*
	18	0	0	1	2	1	1	1	1	2	5*	9*	9

* - denotes critical items (Ie)

(NOTE: maximum value per cell = 10)

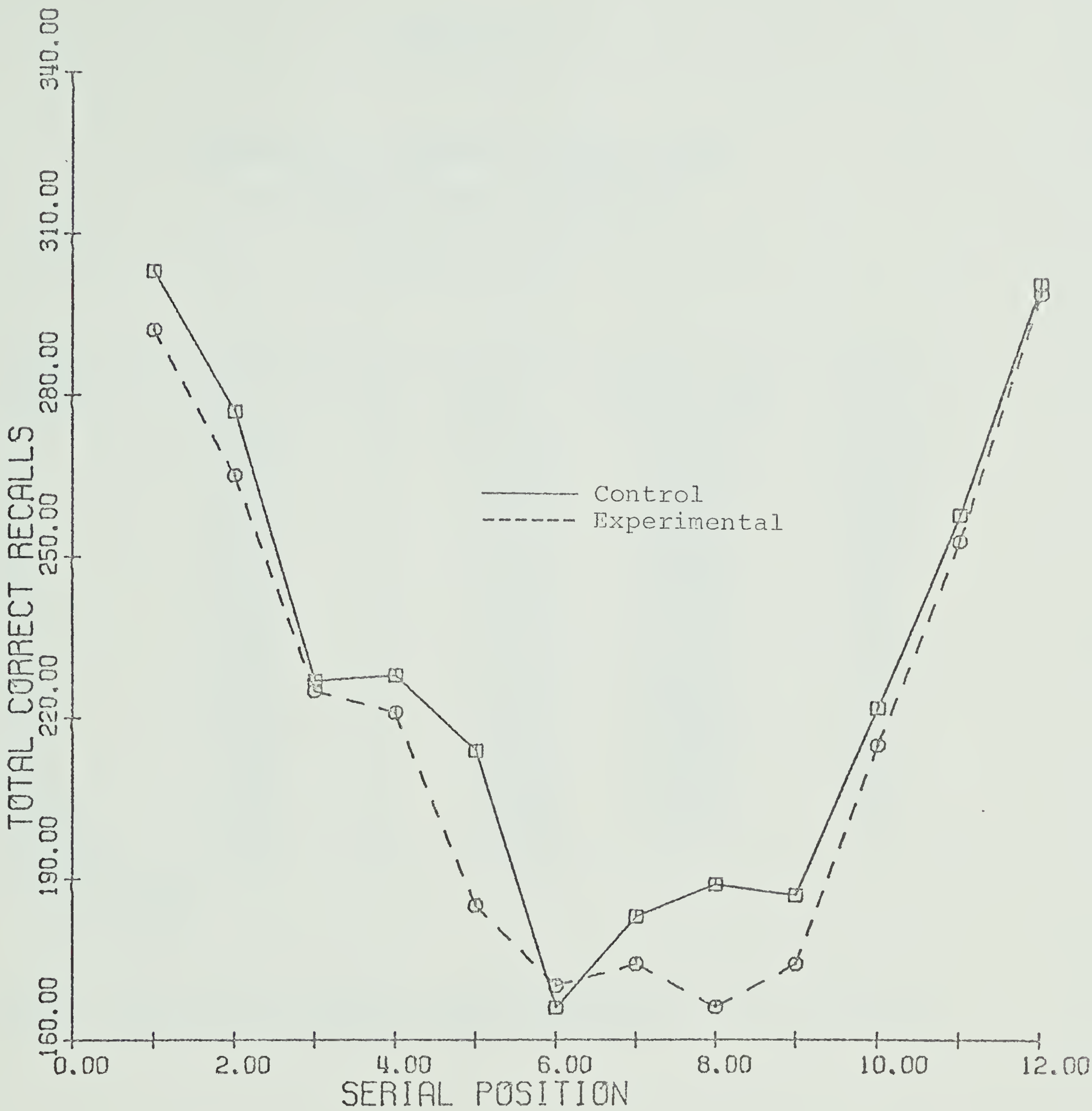

Fig. 1. Serial Position Curves for the Control and Experimental Groups

APPENDIX I

ANALYSIS OF VARIANCE SUMMARY TABLE
FOR OVERALL RECALL PERFORMANCE
BY ALL GROUPS

SOURCE	SS	df	MS	ERROR TERM	F
O	0.017	1	0.017	X (OIRD)	1.34
I	0.228	1	0.228	X (OIRD)	17.81**
R	0.001	1	0.001	X (OIRD)	0.03
D	0.131	3	0.044	X (OIRD)	3.40*
OI	0.001	1	0.001	X (OIRD)	0.05
OR	0.012	1	0.012	X (OIRD)	0.93
IR	0.006	1	0.006	X (OIRD)	0.43
OD	0.009	3	0.003	X (OIRD)	0.23
ID	0.192	3	0.064	X (OIRD)	5.01**
RD	0.027	3	0.009	X (OIRD)	0.70
OIR	0.001	1	0.001	X (OIRD)	0.10
OID	0.018	3	0.006	X (OIRD)	0.47
ORD	0.031	3	0.010	X (OIRD)	0.80
IRD	0.022	3	0.007	X (OIRD)	0.58
OIRD	0.024	3	0.008	X (OIRD)	0.62
X (OIRD)	1.229	96	0.013		

** - $p<.01$
 * - $p<.05$

(NOTE: To avoid confusion, replications has been designated as 'X' in the above table rather than 'R')

APPENDIX II

ANALYSIS OF VARIANCE SUMMARY TABLE

FOR S-WORD (R2)

SOURCE	SS	df	MS	ERROR TERM	F
O	1.313	1	1.313	S(O)	0.07
D	2.894	3	0.965	SD(O)	0.28
I	2.363	1	2.363	SI(O)	0.63
P	397.163	1	397.163	SP(O)	87.11**
S(O)	353.810	18	19.656		
OD	236.615	3	78.872	SD(O)	22.71**
OI	0.800	1	0.800	SI(O)	0.21
DI	2.821	3	0.940	SDI(O)	0.58
OP	0.253	1	0.253	SP(O)	0.06
DP	47.502	3	15.834	SDP(O)	7.08**
IP	1.800	1	1.800	SIP(O)	2.11
SD(O)	187.520	54	3.473		
SI(O)	67.931	18	3.774		
SP(O)	82.064	18	4.559		
ODI	8.931	3	2.977	SDI(O)	1.85
ODP	55.359	3	18.453	SPP(O)	8.25**
OIP	0.176	1	0.176	SID(O)	0.21
DIP	4.044	3	1.348	SDIP(O)	1.20
SDI(O)	87.109	54	1.613		
SDP(O)	120.806	54	2.237		
SIP(O)	15.355	18	0.853		
ODIP	3.327	3	1.109	SDIP(O)	0.99
SDIP(O)	60.789	54	1.126		

** - $p<.01$

APPENDIX III

ANALYSIS OF VARIANCE SUMMARY TABLE

FOR S-WORD (R3)

SOURCE	SS	df	MS	ERROR TERM	F
O	0.897	1	0.897	S(O)	0.03
D	3.479	3	1.160	SD(O)	0.45
I	6.828	1	6.828	SI(O)	2.27
P	1208.921	2	604.461	SP(O)	66.93**
S(O)	507.327	18	28.185		
OD	80.051	3	26.684	SD(O)	10.37**
OI	6.710	1	6.710	SI(O)	2.23
DI	8.945	3	2.982	SDI(O)	2.33
OP	2.542	2	1.271	SP(O)	0.14
DP	132.951	6	22.159	SDP(O)	11.31**
IP	5.234	2	2.617	SIP(O)	1.40
SD(O)	138.960	54	2.573		
SI(O)	54.099	18	3.005		
SP(O)	325.115	36	9.031		
ODI	6.239	3	2.080	SDI(O)	1.62
ODP	42.738	6	7.123	SDP(O)	3.64**
OIP	3.238	2	1.619	SIP(O)	0.86
DIP	2.496	6	0.416	SDIP(O)	0.27
SDI(O)	69.188	54	1.281		
SDP(O)	211.626	108	1.960		
SIP(O)	67.522	36	1.876		
ODIP	4.739	6	0.790	SDIP(O)	0.51
SDIP(O)	165.913	108	1.536		

** - $p<.01$

APPENDIX IV

ANALYSIS OF VARIANCE SUMMARY TABLE

FOR N-WORD (R2)

SOURCE	SS	df	MS	ERROR TERM	F
O	5.200	1	5.200	S(O)	3.44
D	2.780	3	0.927	SD(O)	0.57
I	2.941	1	2.941	SI(O)	1.72
P	145.513	1	145.513	SP(O)	83.59**
S(O)	27.234	18	1.513		
OD	84.482	3	28.161	SD(O)	17.31**
OI	1.830	1	1.830	SI(O)	1.07
DI	1.468	3	0.489	SDI(O)	0.49
OP	1.856	1	1.856	SP(O)	1.07
DP	23.803	3	7.934	SDP(O)	5.16**
IP	2.786	1	2.786	SIP(O)	2.02
SD(O)	87.864	54	1.627		
SI(O)	30.841	18	1.713		
SP(O)	31.334	18	1.741		
ODI	6.545	3	2.182	SDI(O)	2.17
ODP	26.431	3	8.810	SDP(O)	5.73**
OIP	0.515	1	0.515	SIP(O)	0.37
DIP	2.273	3	0.758	SDIP(O)	0.63
SDI(O)	54.390	54	1.007		
SDP(O)	83.092	54	1.539		
SIP(O)	24.860	18	1.381		
ODIP	4.765	3	1.588	SDIP(O)	1.33
SDIP(O)	64.553	54	1.195		

** - $p<.01$

APPENDIX V

ANALYSIS OF VARIANCE SUMMARY TABLE

FOR N-WORD (R3)

SOURCE	SS	df	MS	ERROR TERM	F
O	1.057	1	1.057	S(O)	1.59
D	0.587	3	0.196	SD(O)	0.28
I	2.456	1	2.456	SI(O)	5.38*
P	358.790	2	179.395	SP(O)	158.22**
S(O)	11.945	18	0.664		
OD	15.210	3	5.070	SD(O)	7.24**
OI	0.240	1	0.240	SI(O)	0.53
DI	2.131	3	0.710	SDI(O)	2.17
OP	0.109	2	0.055	SP(O)	0.05
DP	35.757	6	5.960	SDP(O)	9.76**
IP	1.544	2	0.772	SIP(O)	0.93
SD(O)	37.837	54	0.701		
SI(O)	8.220	18	0.457		
SP(O)	40.817	36	1.134		
ODI	3.129	3	1.043	SDI(O)	3.18*
ODP	10.788	6	1.798	SDP(O)	2.94*
OIP	0.585	2	0.292	SIP(O)	0.35
DIP	1.717	6	0.286	SDIP(O)	0.53
SDI(O)	17.713	54	0.328		
SDP(O)	65.952	108	0.611		
SIP(O)	29.777	36	0.827		
ODIP	1.112	6	0.185	SDIP(O)	0.34
SDIP(O)	58.747	108	0.544		

** - $p<.01$
 * - $p<.05$

APPENDIX VI

ANALYSIS OF VARIANCE SUMMARY TABLE

FOR S-ISR (R2)

SOURCE	SS	df	MS	ERROR TERM	F
O	1.097	1	1.097	S(O)	0.61
D	170.857	3	56.952	SD(O)	36.85**
I	21.207	1	21.207	SI(O)	14.44**
S(O)	32.629	18	1.813		
OD	58.835	3	19.612	SD(O)	12.69**
OI	0.172	1	0.172	SI(O)	0.12
DI	9.045	3	3.015	SDI(O)	3.11*
SD(O)	83.448	54	1.545		
SI(O)	26.441	18	1.469		
ODI	1.810	3	0.603	SDI(O)	0.62
SDI(O)	52.402	54	0.970		

** - $p<.01$
* - $p<.05$

APPENDIX VII

ANALYSIS OF VARIANCE SUMMARY TABLE

FOR S-ISR (R3)

SOURCE	SS	df	MS	ERROR TERM	F
O	2.930	1	2.930	S(O)	0.83
D	245.552	3	81.851	SD(O)	48.02**
T	69.179	2	34.589	ST(O)	24.76**
I	24.526	1	24.526	SI(O)	13.10**
S(O)	63.289	18	3.516		
OD	32.676	3	10.892	SD(O)	6.39**
OT	0.591	2	0.296	ST(O)	0.21
DT	61.351	6	10.225	SDT(O)	15.78**
OI	2.067	1	2.067	SI(O)	1.10
DI	10.364	3	3.455	SDI(O)	4.35**
TI	5.230	2	2.615	STI(O)	4.22*
SD(O)	92.045	54	1.705		
ST(O)	50.301	36	1.397		
SI(O)	33.693	18	1.872		
ODT	18.620	6	3.103	SDT(O)	4.79**
ODI	2.239	3	0.746	SDI(O)	0.94
OTI	0.901	2	0.450	STI(O)	0.73
DTI	4.103	6	0.684	SDTI(O)	1.11
SDT(O)	69.999	108	0.648		
SDI(O)	42.856	54	0.794		
STI(O)	22.315	36	0.620		
ODTI	4.851	6	0.809	SDTI(O)	1.32
SDTI(O)	66.360	108	0.614		

** - $p<.01$
 * - $p<.05$

APPENDIX VIII

ANALYSIS OF VARIANCE SUMMARY TABLE

FOR OSR (R2)

SOURCE	SS	df	MS	ERROR TERM	F
O	0.141	1	0.141	S(O)	1.86
D	2.573	3	0.858	SD(O)	12.86**
I	1.860	1	1.860	SI(O)	22.03**
S(O)	1.363	18	0.076		
OD	0.801	3	0.267	SD(O)	4.00*
OI	0.113	1	0.113	SI(O)	1.34
DI	0.189	3	0.063	SDI(O)	1.84
SD(O)	3.602	54	0.067		
SI(O)	1.520	18	0.084		
ODI	0.192	3	0.064	SDI(O)	1.87
SDI(O)	1.846	54	0.034		

** - $p<.01$
* - $p<.05$

APPENDIX IX

ANALYSIS OF VARIANCE SUMMARY TABLE

FOR OSR (R3)

SOURCE	SS	df	MS	ERROR TERM	F
O	0.117	1	0.117	S(O)	3.55
D	5.020	3	1.673	SD(O)	49.70**
T	1.260	2	0.630	ST(O)	16.48**
I	3.008	1	3.008	SI(O)	43.89**
S(O)	0.594	18	0.033		
OD	0.344	3	0.115	SD(O)	3.41*
OT	0.213	2	0.107	ST(O)	2.79
DT	0.922	6	0.154	SDT(O)	2.65*
OI	0.013	1	0.013	SI(O)	0.19
DI	1.618	3	0.539	SDI(O)	18.65**
TI	0.516	2	0.258	STI(O)	7.71**
SD(O)	1.818	54	0.034		
ST(O)	1.376	36	0.038		
SI(O)	1.234	18	0.069		
ODT	0.510	6	0.085	SDT(O)	1.47
ODI	0.211	3	0.070	SDI(O)	2.43
OTI	0.024	2	0.012	STI(O)	0.35
DTI	0.311	6	0.052	SDTI(O)	0.86
SDT(O)	6.261	108	0.058		
SDI(O)	1.562	54	0.029		
STI(O)	1.205	36	0.033		
ODTI	0.212	6	0.035	SDTI(O)	0.58
SDTI(O)	6.521	108	0.060		

** - $p<.01$
* - $p<.05$